

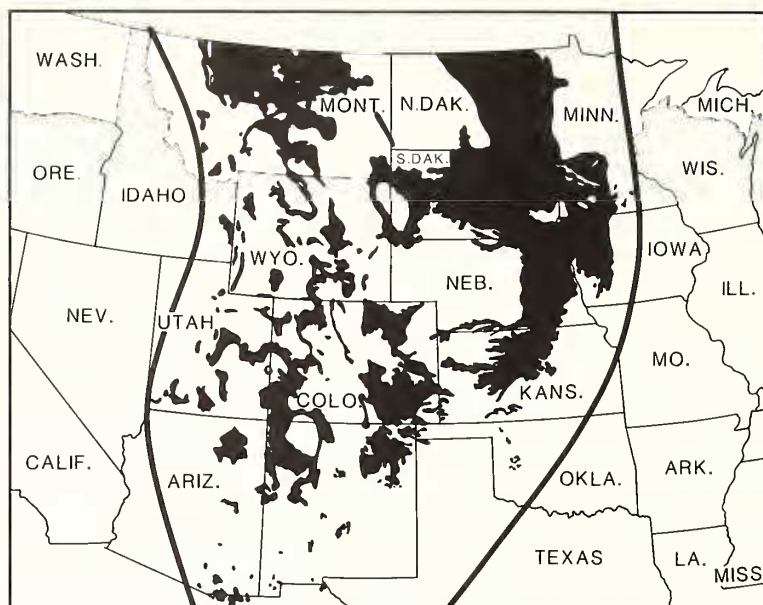
# CENOMANIAN MICROMORPHIC AMMONITES FROM THE WESTERN INTERIOR OF THE USA

by W. J. KENNEDY and W. A. COBBAN

**ABSTRACT** – Calcareous concretions from middle and upper Cenomanian (Cretaceous) shale sequences in Montana and Wyoming yield, on rare occasions, abundant minute ammonites. Some are juveniles of large species, and give valuable evidence on early ontogeny and evolutionary affinities of these taxa. They provide evidence for the probable evolutionary origins of a series of hitherto undescribed progenic dwarf genera, adult at 4.5–16.5 mm diameter that are a remarkable feature of these assemblages. Five new genera, *Kastanoceras*, *Alzadites*, *Microsulcatoceras*, *Cryptometoicoceras* and *Buccinammonites* are introduced. 33 species are described from Montana, Wyoming, Utah, New Mexico and Texas; 16 are new, the others were previously unknown in the region or show new details of early ontogeny. New taxa are: *Moremanoceras montanaense* sp. nov.; *Cunningtoniceras* sp. juv.; *Tarrantoceras exile* sp. nov.; *Kastanoceras spiniger* gen. et sp. nov.; *Alzadites alzadensis* gen. et sp. nov.; *A. westonensis* gen. et sp. nov.; *A. incomptus* gen. et sp. nov.; *Alzadites?* sp.; *Alzadites* sp. A; *Microsulcatoceras puzosiiforme* gen. et sp. nov.; *M. crassum* gen. et sp. nov.; *M. texanum* gen. et sp. nov.; *Microsulcatoceras* sp. ?; *Cryptometoicoceras mite* gen. et sp. nov.; *Nannometoicoceras nanos* sp. nov.; *Nannometoicoceras?* *glaber* sp. nov.; *Buccinammonites minimus* gen. et sp. nov.; *Idiohamites pulchellus* sp. nov.; *I. bispinosus* sp. nov.; *Carthaginites aquilonius* sp. nov.; and *Scaphites* (*Scaphites*) sp.

OVER wide areas of the Western Interior of the United States (text-fig. 1), marine rocks of middle to late Cenomanian age are partly or wholly in a non-calcareous shale facies. Most of the fauna known from this facies comes from calcareous concretions of early diagenetic origin, although in some units, crushed moulds can be obtained by splitting shales. At many levels concretions are only sparingly fossiliferous, and even then yield only large fossils. In the present communication we describe some remarkable faunas collected over the past 60 years from concretions in the Middle to Upper Cenomanian part of the Belle Fourche Shale of the Black Hills in Wyoming and Montana. In this area we estimate that less than 1% of concretions are fossiliferous, and only six out of thousands examined preserve minute ammonites in abundance (text-fig. 2) although others preserve larger fossils, including both macro- and microconch ammonites. This preservation is all the more remarkable, since adjacent concretions at the same stratigraphic horizon at the same locality lack such assemblages. Occurrence is not simply a matter of concretions preserving a particular level of fossil concentration, the occurrences are areally limited. The palaeogeographical setting of the Black Hills area during late Cenomanian time places it far from shore, and we find it difficult to interpret these fossil occurrences as current accumulations, especially as some ammonites preserve delicate features of ornament, and occur scattered throughout the concretions rather than concentrated on a single plane. It is also difficult to accept the occurrences as faecal concentrations for the fossils are embedded in sediment matrix, and are in this respect unlike the great mass occurrences of ammonites in the Mowry Shale (Reeside and Cobban 1954, 1960), where the fossils are bound in a matrix of fish scales and debris.

The occurrences provide a unique opportunity to study elements of the late Cretaceous ammonite fauna of the Western Interior that were previously unrecognized, especially a series of micromorphs, ammonites that are adults at 4.5 to 16.5 mm diameter. Five new micromorph genera and 12 new species are described, including several additional micromorphs from areas in New Mexico, Utah and northeast Texas. Most have adult phragmocone whorls that share common features with the innermost ornamented phragmocone whorls of co-occurring 'normal' size dimorphic ammonites.



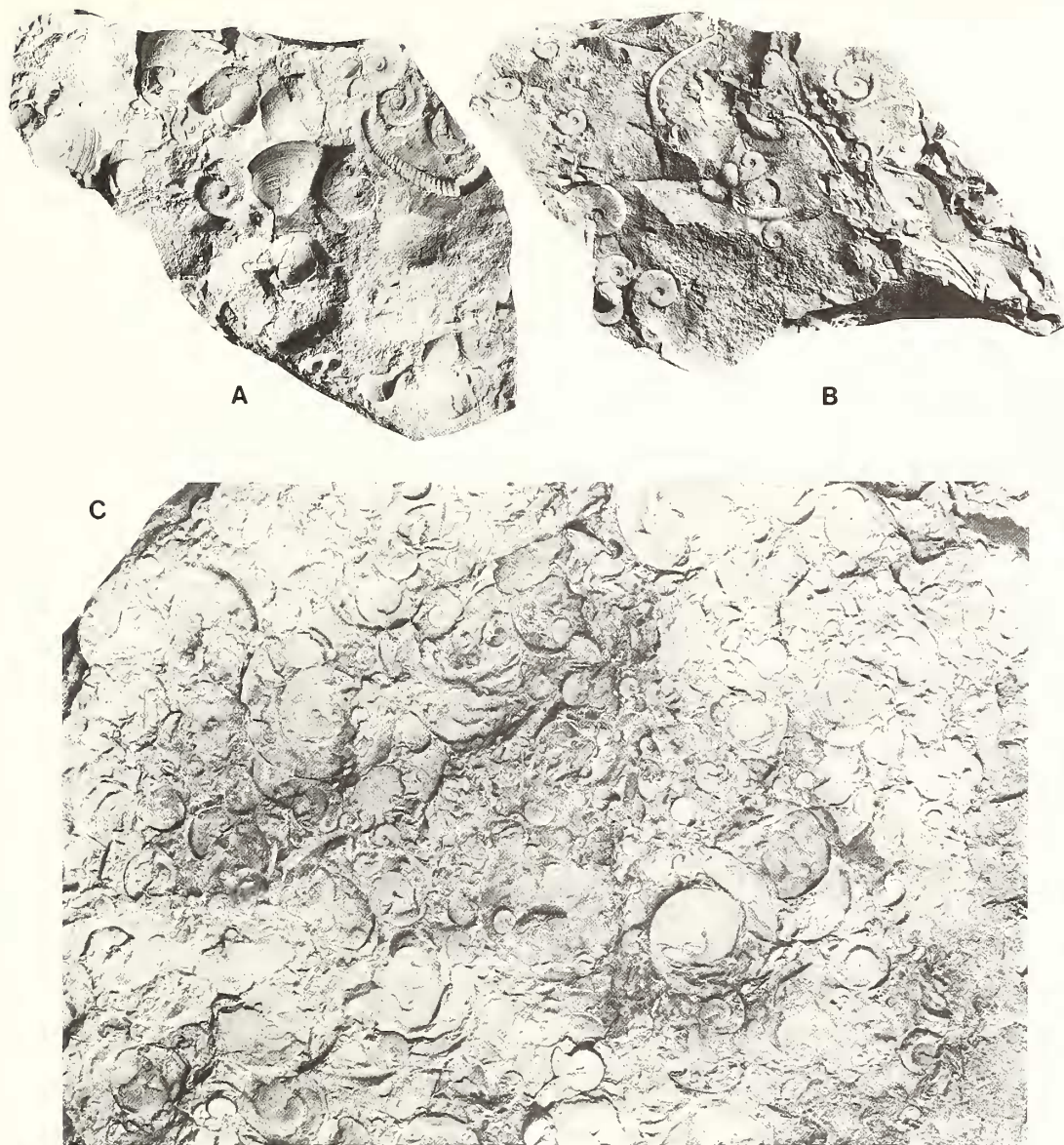
TEXT-FIG. 1. Map of outcrop areas of Cretaceous sedimentary rocks in the Western Interior of the United States. The heavy black bounding lines show the maximum known extent of the mid-Cretaceous seaway. Modified from Cobban and Reeside, 1952, fig. 1.

We interpret the new genera as progenic dwarfs that evolved through precocious sexual maturation, an evolutionary process previously invoked to explain the origin of certain other Upper Cretaceous micromorphs, notably *Protacanthoceras* Spath, 1923 from *Acanthoceras* Neumayr, 1875 (Wright and Kennedy 1980, 1987; Kennedy and Wright 1985); *Nannometoicoceras* Kennedy, 1988, from *Metoicoceras* Hyatt, 1903 (Kennedy 1988, p. 63); *Plesi-acanthoceratoides* Kennedy and Cobban, 1990, from the Western Interior acanthoceratine lineage.

These micromorphs are not, it must be stressed, juveniles of 'normal' sized taxa. They show all the features of maturity common to ammonites, including septal crowding, modification of ornament on the body chamber, and development of distinctive apertural processes. Several of the taxa are monotypic, or represented by few specimens. We justify naming them because they are so distinctive and utterly different in most cases from all previously known taxa. We also hope that their description will stimulate other workers to look carefully for such micromorphs amongst apparent juveniles in their own collections, since we consider it unlikely that the Western Interior occurrences are unique to that region.

What the life habits of these micromorphs may have been is a matter of speculation. Their concentrated occurrence suggests to us that some at least may have lived close to the bottom where they were preserved, because we cannot easily accept or see evidence for any physical or biological process that led to their concentration.

Micromorphs apart, the concretion faunas studied include abundant juvenile individuals that show for the first time the early ontogenetic development of several genera and species, clarifying their affinities and also pointing to the possible ancestors of the progenic dwarfs. Also present are a series of taxa that are either new, or not previously recorded from the area, including first records of *Sumitomoceras* in the region, and the first *Scaphites* (*Scaphites*) from the Cenomanian of the Western Interior. In all, 33 species are documented.



TEXT-FIG. 2. Mass occurrence of small ammonites in concretions. A, B, USNM 423785 and 423784 from USGS Mesozoic locality 22871, *Plesiakanthoceras wyomingense* zone, with *Borissiakoceras* and heteromorphs. C, USNM 423665, from USGS Mesozoic locality 528, Frontier Formation, Middle Cenomanian, 1.5 km (1 mile) northeast of Wilcox, Albany County, Wyoming, with *Johnsonites sulcatus* Cobban, 1961. Collected by Alpheus Hyatt and I. C. Russel in 1888.

#### BIOSTRATIGRAPHY

The standard ammonite zonation for the Middle and Upper Cenomanian of the Western Interior is shown in text-fig. 3, and is modified after the work of Cobban (1984, 1987a). These are assemblage zones, the bases of the zones marked by the first appearance of a variety of ammonites, including the index species, which is usually, but not invariably limited to its zone. Because of the limited



CRETACEOUS STAGE		AMMONOID ZONE	USGS MESOZOIC LOCALITY
Cenomanian (part)	upper	<i>Nigericeras scotti</i>	
		<i>Neocardioceras juddii</i>	
		<i>Vascoceras cauvinii</i>	
		<i>Sciponoceras gracile</i>	← 23042, D12052
		<i>Metoicoceras mosbyense</i>	← D8314 ← 12650, 12740
		<i>Dunveganoceras pondi</i>	← D4462, D4466, D5947
	middle	<i>Plesiacanthoceras wyomingense</i>	← 22871
		<i>Acanthoceras amphibolum</i>	
		<i>Acanthoceras bellense</i>	
		<i>Acanthoceras muldoonense</i>	
		<i>Acanthoceras granerosense</i>	
		<i>Conlinoceras tarrantense</i>	

TEXT-FIG. 3. Middle and Upper Cenomanian ammonite zones of the US Western Interior, with the levels of some of the more important collections indicated.

vertical and horizontal distributions of ammonites within sedimentary sequences which result from both sedimentary and biological controls, these zones are of different scales and may be recognized over quite limited areas (as in the case of the *Conlinoceras tarrantense* to *Acanthoceras bellense* zones), while others can be recognized throughout the Western Interior (e.g. the *Acanthoceras amphibolum* zone). The oldest fauna described here comes from the *Plesiacanthoceras wyomingense* zone, which is placed at the top of the Middle Cenomanian. The *Dunveganoceras pondi* zone has *Calycoceras* (*Proeulcalycoceras*) *canitaurinum* Haas, 1949 as an alternative index species in the southern part of the Interior, where *D. pondi* is absent. Their contemporaneity is established by the co-occurrence of the two index species at their common type locality near Greybull, Wyoming as well as common occurrence of other species. The *Metoicoceras mosbyense* zone is represented by a great thickness of sediment in the northern Western Interior, and may represent a greater time interval than the other Upper Cenomanian zones, although not susceptible to finer division at present. *Sciponoceras gracile* is retained as a zonal index because of long and widespread usage and because it is by far the commonest ammonite at that level although it ranges up to the *Neocardioceras juddii* zone. *Metoicoceras geslinianum* (d'Orbigny, 1850), *M. whitei* Hyatt, 1903 (a synonym) and *Euomphaloceras* [*Kanabicer*] *septemseriatum* (Cragin, 1893) have also been used as indices for this zone in recent years.

Suggestions that the *S. gracile* zone can be divided into a lower subzone of *Vascoceras diartianum* (d'Orbigny, 1850) and an upper subzone of *E. septemseriatum* (Cobban 1984, p. 81) are here abandoned; *V. diartianum* occurs below the base of the *gracile* zone in association with *Euomphaloceras euomphalum* (Sharpe, 1855), *Eulcalycoceras pentagonum* (Jukes-Browne, 1896) and other ammonites in southwestern New Mexico and the Black Hills area at the top of the *M. mosbyense* zone.

*Vascoceras cauvinii* Chudeau, 1909, was proposed as a provisional index for a distinctive and as yet undescribed fauna between the *S. gracile* and *N. juddii* zones known only from southwest New Mexico. Subsequent work shows *V. cauvinii* to range down into the correlatives of the *gracile* zone in Israel (Lewy, Kennedy and Chancellor 1984), and up into the *Neocardioceras juddii* zone at Chispa Summit in Trans-Pecos Texas, and a replacement index for the zone is needed from among the, at present, undescribed *Euomphaloceratinae* present in the assemblage.



The *Neocardioceras juddii* zone can be recognized in Trans-Pecos Texas, New Mexico, Colorado, Arizona, Utah, Wyoming and Montana. Apart from the index species (which is the last of a lineage of *Neocardioceras* that extends down to the *D. pondi* zone), *Pseudaspidoceras pseudonodosoides* (Choffat, 1898) is locally common in Trans-Pecos Texas and New Mexico and there is also a diverse, but as yet undescribed, vascoceratid and pseudotissotid fauna in these two states. Suggestions that *Gauthiericeras* aff. *bravaisi* (d'Orbigny) of Moreman (1927, p. 96, pl. 4, fig. 2) was an *N. juddii* (Wright and Kennedy 1981, p. 50) and indicated the presence of the *juddii* zone in northeast Texas must be discounted; subsequent work shows Moreman's form to be lower Turonian *Watinoceras* (Kennedy 1988, p. 50).

The highest Cenomanian zone recognized here has *Nigericeras scotti* Cobban, 1972, as index species, the index species itself being limited to southeast Colorado and northeastern and southwestern New Mexico.

### LOCALITY DETAILS

The more important localities of ammonites described below are shown on text-fig. 4 and their stratigraphic positions are shown in text-fig. 3. Where localities have yielded only limited numbers of specimens, details are given at the appropriate point in the text. Nine localities yielded large assemblages, and in the interests of brevity, full details and faunal lists are given here.

*USGS Mesozoic locality 12650.* Collected by W. W. Rubey and others, 1924. Sec. 7, T. 48 N., R. 65 W., 3.2 km southeast of Thornton, Weston County, Wyoming. Belle Fourche Shale, 18.3 m (60 feet) beneath highest yellow concretion. Upper Cenomanian *Metoicoceras mosbyense* zone. Ammonite fauna is: *Borissiakoceras* sp. juv., *Moremanoceras costatum* Cobban, Hook and Kennedy, 1989 (common), *Cunningtoniceras* sp. juv., *Tarrantoceras exile* sp. nov., *Metoicoceras* cf. *mosbyense* Cobban, 1953 (juveniles), *Carthaginites aquilonius* sp. nov.

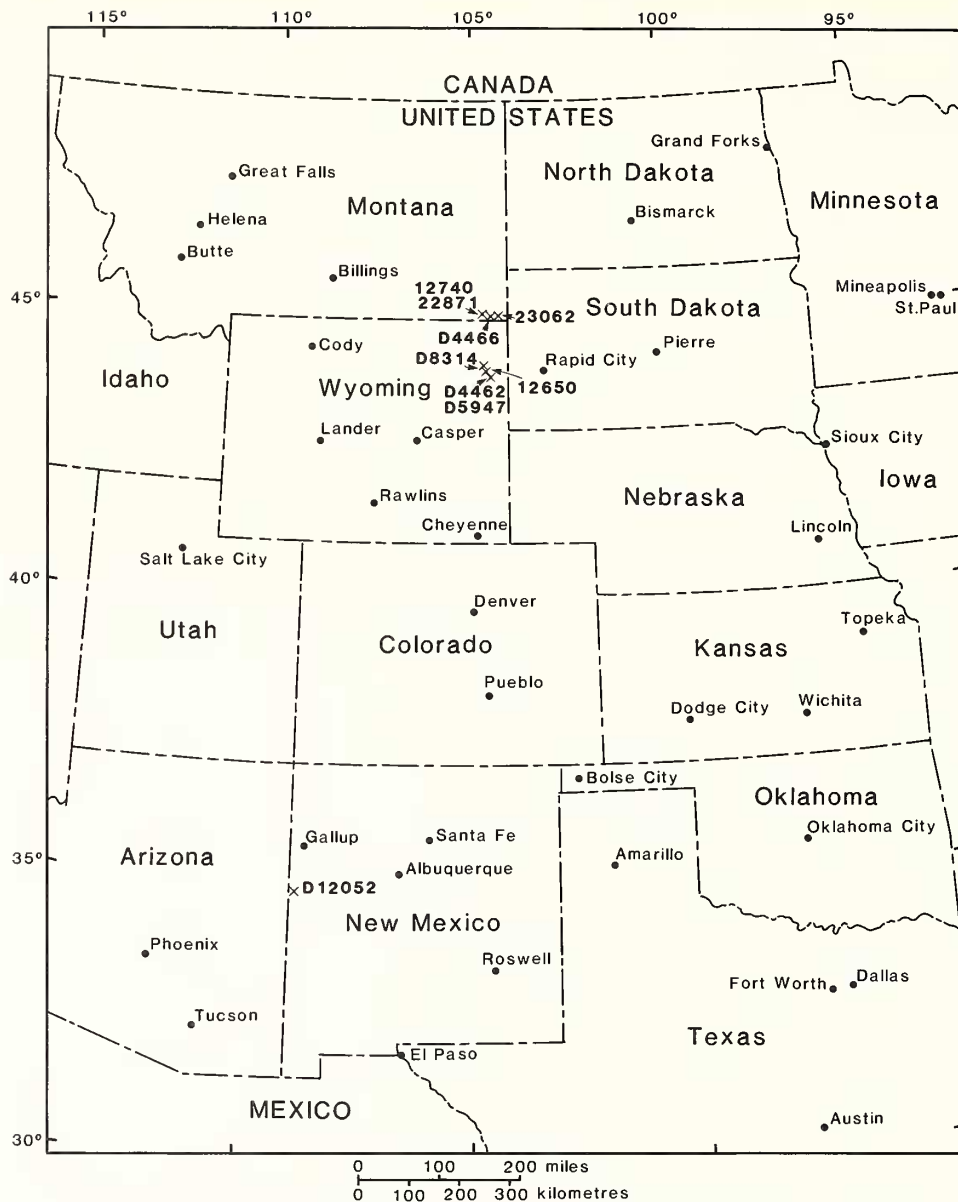
*USGS Mesozoic locality 12740.* Collected by M. N. Bramlette and W. W. Rubey, 1924. E $\frac{1}{2}$  sec. 6, T. 9 S., R. 59 E., Carter County, Montana. Belle Fourche Shale. Upper Cenomanian *Metoicoceras mosbyense* zone. Ammonite fauna is: *Moremanoceras costatum* (common), *Neocardioceras* sp. nov., *Nannometoicoceras nanos* gen. et sp. nov., *Metoicoceras* cf. *mosbyense* (juveniles).

*USGS Mesozoic locality 23062.* Collected by J. B. Reeside Jr., W. A. Cobban and H. R. Christner. 0.8 km east of Five Mile Creek, in the SE $\frac{1}{4}$  Sec. 25, T. 9 S., R. 60 E., Carter County, Montana. Greenhorn Formation. Upper Cenomanian *Sciponoceras gracile* zone. The ammonite fauna is: *Borissiakoceras* sp., *Sunitomoceras* sp. juv., *Kanabicerias septemseriatum* (Cragin, 1893), *Buccinammonites minutus* gen. et sp. nov., *Microsulcatoceras puzosiforme* gen. et sp. nov., *Metoicoceras geslinianum* (d'Orbigny, 1850), *Cryptometoicoceras mite* gen. et sp. nov., *Allocriceras annulatum* (Shumard, 1860), *Sciponoceras gracile* (Shumard, 1860) (common), *Yezoites delicatulus* (Warren, 1930).

*USGS Mesozoic locality 22871.* Collected by W. A. Cobban, 1947. 9.7 km northwest of Alzada in SE $\frac{1}{4}$  Sec. 6, T. 9 S., R. 59 E., Carter County, Montana. Middle Cenomanian *Plesiacanthoceras wyomingense* zone. *Borissiakoceras orbiculatum* Stephenson, 1955 (common), *Moremanoceras straini* Kennedy, Cobban and Hook, 1988, *M. montanense* sp. nov., *Plesiacanthoceratoides alzadense* (Cobban, 1987b), *Plesiacanthoceras wyomingense* (Reagan, 1924), *Tarrantoceras cuspidum* Stephenson, 1953, *Tarrantoceras* sp., *Kastanoceras spiniger* gen. et sp. nov., *Alzadites alzadensis* gen. et sp. nov., acanthoceratinae indet., *Hamites cimarronensis* (Kaufmann and Powell, 1977) (common), *Idiohamites pulchellus* sp. nov., *I. bispinosus* sp. nov., *Anaptychus* sp.

*USGS Mesozoic locality D4462.* Collected by W. A. Cobban, 1964. NW $\frac{1}{4}$  NE $\frac{1}{4}$  NE $\frac{1}{4}$  Sec. 24, T. 47 N., R. 65 W., Weston County, Wyoming. Belle Fourche Shale. Upper Cenomanian *Dunveganoceras pondi* zone. Ammonite fauna is: *Borissiakoceras orbiculatum*, *Metoicoceras* aff. *praecox* Haas, 1949, *Cryptometoicoceras mite* gen. et sp. nov., *Hamites cimarronensis*, *Idiohamites bispinosus*.

*USGS Mesozoic locality D4466.* Collected by W. A. Cobban, 1964. 4.8 km NW of Alzada in NE $\frac{1}{4}$  NW $\frac{1}{4}$  Sec. 14, T. 9 S., R. 59 E., Carter County, Montana. Belle Fourche Shale, near bentonite G of Knechtel and Patterson (1962). Upper Cenomanian, *Dunveganoceras pondi* zone. Ammonite fauna is: *Borissiakoceras* sp.,



TEXT-FIG. 4. Locality map for some of the more important localities mentioned in the text.

*Moremanoceras costatum*, *Tarrantoceras cuspidum*, *Tarrantoceras* sp., *Dunveganoceras pondi* Haas, 1949, *Hamites cimarronensis*, *Idiohamites bispinosus* sp. nov.

USGS Mesozoic locality D5947. Collected by W. A. Cobban, 1961. 4.8 km south of Upton in NW $\frac{1}{4}$  sec. 14, T. 47 N., R. 65 W., Weston County, Wyoming. Belle Fourche Shale, 19.8 m (65 feet) above 0.6 m (2 feet) bentonite. Upper Cenomanian, *Dunveganoceras pondi* zone. Ammonite fauna is: *Borissiakoceras* cf. *orbiculatum*, *Moremanoceras costatum*, *Tarrantoceras* sp., *Neocardioceras* sp. nov., *Plesiocanthoceras* cf. *bellsanum* (Stephenson, 1953), *P.* cf. *wyomingense*, *Alzadites westonense* gen. et sp. nov., *Alzadites*? sp., *Metoicoceras* sp. A; *Hamites cimarronensis*, *Idiohamites bispinosus* sp. nov.

USGS Mesozoic locality D8314. Collected by E. A. Merewether, 1971. SE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 33, T. 50 N., R. 66 W., Crook County, Wyoming. Belle Fourche Shale, from ferruginous concretions 7.6–10.7 m (25–35 feet) below top. Upper Cenomanian, *Metoicoceras mosbyense* zone. Ammonite fauna is: *Borissiakoceras* sp. juv., *Moremanoceras scotti*, *Euomphaloceras merewetheri* Cobban, Hook and Kennedy, 1989, *Hamites salebrosus* Cobban, Hook and Kennedy, 1989, *Metaptychoceras* sp.

USGS Mesozoic locality D12052. Collected by S. C. Hook, O. J. Anderson and W. A. Cobban, 1982. Near mouth of Yellowrock Canyon in NW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 17, T. 7 N., R. 20 W., Cibola County, New Mexico. Rio Salado Tongue of Mancos Shale, from white concretions 4.6 m (15 feet) above base. Upper Cenomanian *Sciponoceras gracile* zone. Ammonite fauna is: *Pseudocalycoceras angolaense* (Spath, 1931), *Euomphaloceras septemseriatum*, *Sumitomoceras* sp. juv., *Metoicoceras geslinianum*, *Nannometoicoceras? glabrum* gen. et sp. nov., *Allocrioceras amulatum* (Shumard, 1860), *Sciponoceras gracile*, *Worthoceras vermiculus* (Shumard, 1860).

## REPOSITORIES OF SPECIMENS

The following abbreviations are used to indicate the repositories of collections: TMM: University of Texas Memorial Museum, Austin, Texas. USNM: National Museum of Natural History, Washington, DC. AMNH: American Museum of Natural History, New York.

## CONVENTIONS

All diameters are given in millimetres; D = diameter; Wb = whorl breadth; Wh = whorl height; U = umbilicus; ic = intercostal dimension; c = costal dimension. Figures in parentheses are dimensions as a percentage of the diameter. The term rib index as applied to heteromorphs is the number of ribs in a distance equal to the whorl height at the mid-point of the interval where the count was taken. The suture terminology of Wedekind (1916) as propounded by Kullmann and Wiedmann (1970) is used here with E = external lobe, L = lateral lobe, U = umbilical lobe and I = internal lobe.

## SYSTEMATIC PALAEOLOGY

Order AMMONOIDEA Zittel, 1884, pp. 355, 392

Suborder AMMONITINA Hyatt, 1889, p. 7

Superfamily HAPLOCERATAEAE Zittel, 1884, p. 463

Family BINNEYITIDAE Reeside, 1928, p. 4

Genus BORISSIAKOCERAS Arkhanguelsky, 1916, p. 55

*Type species.* By original designation: *Borissiakoceras mirabilis* Arkhanguelsky, 1916, p. 55, pl. 8, figs. 2, 3.

*Borissiakoceras orbiculatum* Stephenson, 1955

Plate 1, figs. 1–39; Plate 4, figs. 78–83

1955 *Borissiakoceras orbiculatum* Stephenson, p. 64, pl. 6, figs. 1–4.

1961 *Borissiakoceras orbiculatum* Stephenson; Cobban, p. 750, pl. 88, figs. 15–41; text-figs. 5a–f (with synonymy).

1988 *Borissiakoceras orbiculatum* Stephenson; Kennedy, p. 18, pl. 1, figs. 23–26 (with synonymy).

1990 *Borissiakoceras orbiculatum* Stephenson, 1955; Kennedy and Cobban, p. 85, pl. 1, figs. 1–14.

*Holotype.* USNM 108832 from the basal Eagle Ford Group on Walnut Creek, 7.6 km (4.75 miles) northeast of Mansfield, Texas. Middle Cenomanian, *Acanthoceras amphibolum* zone.

*Material.* More than 100 specimens, including USNM 423646–423665, from USGS Mesozoic locality 22871, *Plesiacanthoceras wyomingense* zone.

*Discussion.* Cobban (1961) described this species in some detail and indicated how it differed from others referred to the genus. The present collection contains 50 specimens that were suitable for



measurement. Of these, 35 were microconchs and 13 macroconchs, two being unassigned. Microconchs (Pl. 1, figs. 1–8, 26–38) are adult at 5–11 mm diameter and have umbilical ratios of 0.21–0.32. Macroconchs (Pl. 1, figs. 9–25, 39) are adult at 9.7–27.3 mm and have umbilical ratios of 0.13–0.19.

*Occurrence.* *Acanthoceras amphibolum* zone of Wyoming, Colorado, Kansas and Texas; *Plesiocanthoceras wyomingense* zone of Montana; *Sciponoceras gracile* zone of Texas.

Superfamily DESMOCERATACEAE Zittel, 1895, p. 426

(*nom.trans.* Wright and Wright, 1951, p. 18;

*ex* Desmoceratidae Zittel, 1895)

Family DESMOCERATIDAE Zittel, 1895, p. 426

Subfamily DESMOCERATINAE Zittel, 1895, p. 426

Genus MOREMANOCERAS Cobban, 1972, p. 465

*Type species.* *Tragodesmoceras scotti* Moreman, 1942, p. 208, pl. 33, fig. 8, text-fig. 2D; by original designation.

*Moremanoceras straini* Kennedy, Cobban and Hook, 1988

Plate 1, figs. 40–45, 55, 56, 60–72

1955 *Desmoceras?* sp. Stephenson, p. 58, pl. 4, figs. 12, 13.

1977a *Desmoceras* (*Pseudouligella*) aff. *D. japonicum* Yabe; Cobban, p. 22, pl. 11, figs. 1–6, 9, 10.

1977b *Desmoceras* (*Pseudouligella*) aff. *japonicum* Yabe; Cobban, fig. 4a–c.

1988 *Moremanoceras straini* Kennedy, Cobban and Hook, p. 36, fig. 1a–g, i–l.

*Types.* Holotype is USNM 416051 by original designation; paratypes USNM 416052–416060, from the base of the Boquillas Formation, Cerro de Cristo Rey, New Mexico, *Acanthoceras amphibolum* zone.

*Material.* More than 60 specimens, including USNM 423667–423673, from USGS Mesozoic locality 22871, *Plesiocanthoceras wyomingense* zone.

*Discussion.* Many of the present specimens retain original shell; specimens studied range from 2.5 to 67 mm diameter. The diagnostic features of the species are the compressed to slightly depressed

#### EXPLANATION OF PLATE 1

Figs. 1–39. *Borissiakoceras orbiculatum* Stephenson, 1955. 1, USNM 423646; 2, USNM 423647; 3–5, USNM 423648; 6, 30, USNM 423649; 7, 8, 34, 35, USNM 423656; 9–11, USNM 423650; 12, USNM 423651; 13, 14, USNM 423652; 15–17, USNM 423653; 18, 19, USNM 423654; 20, 21, 39, USNM 423655; 22, 23, USNM 423657; 24, 25, USNM 423658; 26, 27, USNM 423659; 28, USNM 423660; 29, USNM 423661; 31–33, USNM 423662; 36–38, USNM 423666, all from USGS Mesozoic locality 22871, *Plesiocanthoceras wyomingense* zone.

Figs. 40–45, 55, 56, 60–72. *Moremanoceras straini* Kennedy, Cobban and Hook, 1988. 40–42, USNM 423667; 43–45, USNM 423668; 55, 56, 60–62, USNM 423669; 63–65, USNM 423670; 66–68, USNM 423671; 69, 70, USNM 423672; 71, 72, USNM 423673, all from USGS Mesozoic locality 22871, *Plesiocanthoceras wyomingense* zone.

Figs. 46–48, 52–54. *Moremanoceras costatum* Cobban, Hook and Kennedy, 1989. 46–48, USNM 423676; 52–54, USNM 423690, from USGS Mesozoic locality D4466, *Dumveganoceras pondi* zone.

Figs. 49–51, 57–59. *Moremanoceras scotti* (Moreman, 1942). 49–51, USNM 423674; 57–59, USNM 423675, from USGS Mesozoic locality D8314, *Metoicoceras mosbyense* zone.

Figs. 15–17, 26–35, 39 are  $\times 2$ ; Figs. 18, 19, 36–38 are  $\times 3$ ; the remainder  $\times 1$ .



whorls, biconcave growth lines on the shell surface (Pl. 1, figs. 60, 64, 67) and periodic constrictions on the mould, both of which form an acute chevron on the venter (Pl. 1, figs. 61, 65, 70). The venter is initially evenly rounded (Pl. 1, figs. 40–45) but a blunt, rounded keel develops at maturity (Pl. 1, figs. 69–72) as do blunt adapical collars to the constrictions. *Moremanoceras elgini* (Young, 1958) (p. 292, pl. 39, figs. 4–20, 24, 25, 30, 31; text-fig. 1a–e) is more compressed when young, develops thickened collar-ribs to the constrictions from 15 mm diameter, has strong ventrolateral flank ribs when mature and never has a siphonal keel or ridge.

*M. costatum* Cobban, Hook and Kennedy (1989) has a sharp keel that is present from a much earlier stage and strong concave ribs on the ventrolateral shoulder. *M. montanaense* sp. nov., described below, is a large, stout species that has ribs that are straight on the flanks rather than biconcave, and lacks the pronounced ventral chevron and keel of *M. straini*. *M. scotti* (Moreman, 1942) (p. 208, pl. 33, fig. 8; text-fig. 20; see Cobban, 1972, p. 6, pl. 2, figs. 1–23; text-figs. 3–5) has distant, flared collar ribs that are transverse over the venter, and never develops a keel (Pl. 1, figs. 49–51; 57–59).

*Occurrence.* *A. amphibolum* zone of central and Trans-Pecos Texas; *Plesiocanthoceras wyomingense* zone of Montana.

*Moremanoceras costatum* Cobban, Hook and Kennedy, 1989

Plate 1, figs. 46–48, 52–54; Plate 2, figs. 1–35; Plate 4, figs. 76 and 77

1989 *Moremanoceras costatum* Cobban, Hook and Kennedy, p. 19, figs. 19, 64a–k, 65a–d, g, h (with full synonymy).

*Types.* Holotype is USNM 425133, paratypes USNM 425134–425142, from the *Metoicoceras mosbyense* zone of USGS Mesozoic locality D10186 in Luna County, New Mexico.

*Material.* USNM 423677 to 423683 from USGS Mesozoic locality 12740, all *M. mosbyense* zone. USNM 423684 to 423687 and 423738 from USGS Mesozoic locality D5947; USNM 423676, 423688 and 423690, from USGS Mesozoic locality D4466, are from the *Dunveganoceras pondi* zone.

*Dimensions*

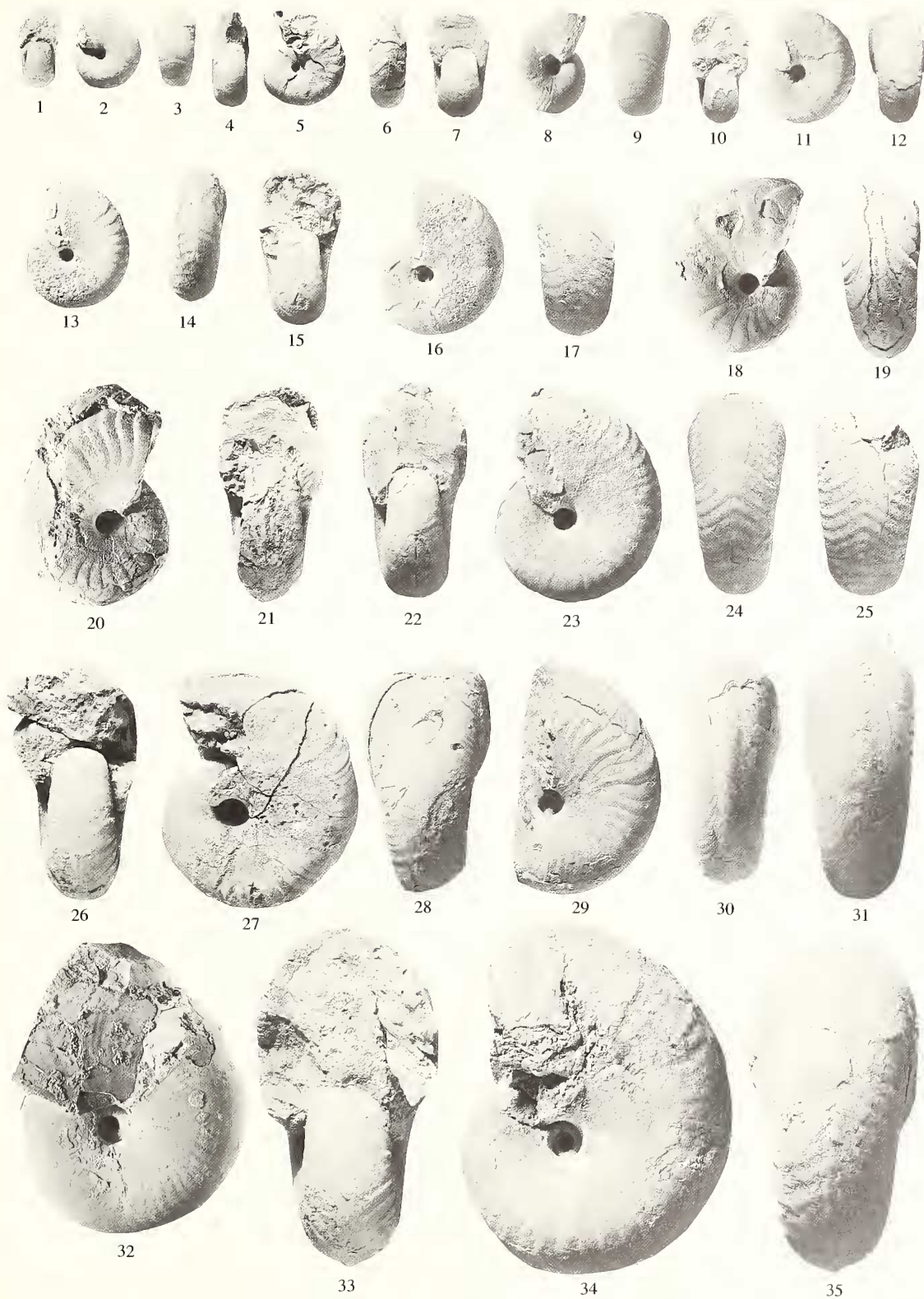
	<i>D</i>	<i>Wb</i>	<i>Wh</i>	<i>Wb: Wh</i>	<i>U</i>
423677	19.5 (100)	6.8 (34.9)	7.2 (36.9)	0.94	0.7 (3.6)
423678	18.2 (100)	9.0 (49.4)	10.5 (57.6)	0.86	1.2 (6.6)
423679	22.2 (100)	12.2 (55.4)	—	—	1.2 (5.4)
423680	25.0 (100)	13.0 (52.0)	13.9 (55.6)	0.94	2.1 (8.4)
423681	33.0 (100)	16.6 (50.3)	18.5 (56.1)	0.90	2.4 (7.3)
423682	36.7 (100)	19.5 (53.1)	20.3 (55.3)	0.96	3.3 (9.0)
423683	57.8 (100)	30.0 (51.9)	33.6 (58.1)	0.89	6.2 (10.7)

*Discussion.* The present material is much better preserved than the types. Very young specimens with shell preserved (Pl. 2, figs. 1–12) show distant feebly flexuous ribs, and moulds bear constrictions that cross the venter in a narrow chevron with an adapical collar-rib. Both ribs and

EXPLANATION OF PLATE 2

Figs. 1–35. *Moremanoceras costatum* Cobban, Hook and Kennedy, 1989. 1–3, USNM 423677; 4–6, USNM 423684; 7–9, USNM 423685; 10–12, USNM 423678; 13, 14, USNM 423679; 15–17, USNM 423680; 18, 19, USNM 423686; 20, 21, USNM 423687; 22–25, USNM 423681; 26–28, USNM 423682; 29–30, USNM 423688; 31, 32, USNM 423689; 33–35, USNM 423683. 1–3, 10–17, 22–28, 33–35 are from USGS Mesozoic locality 12740, *Metoicoceras mosbyense* zone. 4–9, 18–21 are from USGS Mesozoic locality D5947, *Dunveganoceras pondi* zone. 29–30 are from USGS Mesozoic locality D4466, *Dunveganoceras pondi* zone. 31, 32 are from USGS Mesozoic locality 12621, *Dunveganoceras pondi* zone. Figs. 7–9 are  $\times 2$ ; the remainder are  $\times 1$ .





constrictions strengthen as size increases (Pl. 2, figs. 13–35), while a pronounced siphonal ridge is present on the shell from a diameter as small as 20 mm (Pl. 2, figs. 18 and 19). This ridge may be markedly crenulate where crossed by the ribs. Both ribs and keel are present, if less prominent, on large moulds. The presence of pronounced falcoid ribs, especially well-developed on the outer flanks and venter plus the siphonal keel at the apex to a narrow ventral chevron distinguish this species from all others, as is apparent from the discussion under *M. straini* above.

*Occurrence.* *Calycoceras canitaurinum* zone in New Mexico, Trans-Pecos Texas, western Oklahoma, central Kansas and north-central Colorado, and in the correlative *Dunveganoceras pondi* zone in Wyoming and Montana. *Metoicoceras mosbyense* zone in Wyoming and New Mexico.

*Moremanoceras montanaense* sp. nov.

Plate 3, figs. 62–64

*Types.* Holotype is USNM 423691 from USGS Mesozoic locality D12890, in the lower part of the Greenhorn Formation in sec. 5, T. 9 S., R. 59 E., Carter County, Montana. Paratype USNM 423692 is from USGS Mesozoic locality D10201, Colorado Formation, 3 m (10 feet) to 4.6 m (15 feet) above base, NE $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 20, T. 18 S., R. 20 W., Hidalgo County, New Mexico. *M. mosbyense* zone.

*Dimensions*

	<i>D</i>	<i>Wb</i>	<i>Wh</i>	<i>Wb: Wh</i>	<i>U</i>
Holotype					
USNM 423691	60.5 (100)	31.3 (51.7)	36.0 (59.7)	0.86	3.7 (6.1)
at	45.0 (100)	23.0 (51.1)	24.8 (55.1)	0.93	5.6 (12.4)

*Description.* Holotype is a phragmocone 62 mm in diameter, retaining recrystallized shell, and slightly crushed, making accurate measurements impossible. Coiling is very involute, with a tiny, deep umbilicus with a flattened subvertical wall and narrowly rounded umbilical shoulder. Whorl section compressed, with flattened subparallel flanks and broadly rounded venter. Ornament is not visible on the innermost flank, but the mid to outer flanks and venter bear crowded ribs of variable strength and spacing. They arise as mere striae, are feebly convex at mid flank, concave over the outer flank and ventrolateral shoulder and cross the venter in a broad convexity. Periodic interspaces are deepened and presumably correspond to constrictions on the mould. Sutures not seen.

*Discussion.* Large size and density of ribbing, course of ribs and lack of a siphonal ridge immediately separate *M. montanaense* from *M. elgini*, *M. straini* and *M. costatum*. The closest similarities are to *M. scotti* (Moreman, 1942) (p. 208, pl. 33, fig. 8; text-fig. 28; see Cobban, 1972, p. 6, pl. 2, figs. 1–23; text-figs 3–5), but this *Sciponoceras gracile* zone species has very widely separated flared ribs that extend down to the umbilical shoulder, and are separated by very fine riblets and growth striae only in middle and later growth. *M. montanaense* sp. nov. probably arose from *M. costatum* by retention of the ribbed, non-carinate morphology of the juvenile stages of the latter to a large size, plus modification in rib style and elimination of the marked ventral chevron of the later stages of *M. costatum*, leaving the broad ventral curvature of the juvenile (Pl. 2, figs. 1–10). *M. montanaense* sp. nov. in turn probably gave rise to *M. scotti* by differentiation of ribbing during later growth.

*Occurrence.* As for types.

Superfamily ACANTHOCERATAEAE de Grossouvre, 1894, p. 22

(*nom. correct.* Wright and Wright, 1951, p. 24, *pro.* Acanthoceratida Hyatt, 1900, p. 585; *nom. transl. ex* Acanthoceratidae Hyatt, 1900, p. 585; *nom. correct. ex* Acanthoceratidés de Grossouvre, 1894).

## Family ACANTHOCERATIDAE de Grossouvre, 1894, p. 22

(*nom. correct.* Hyatt, 1900, p. 585; *ex* Acanthoceratidés de Grossouvre, 1894, p. 22).

## Subfamily ACANTHOCERATINAE de Grossouvre, 1894, p. 22

(*nom. correct.* Hyatt, 1900, p. 585; *ex* Acanthoceratidés de Grossouvre, 1894; *nom. transl.* Wright and Wright, 1951, p. 28, *ex* Acanthoceratidés de Grossouvre).

## Genus CUNNINGTONICERAS Collignon, 1937, p. 64 (40)

(? = *Guerangericeras* Thomel, 1972, p. 119)

*Type species.* *Ammonites cunningtoni* Sharpe, 1855, p. 35, pl. 15, fig. 2.

*Cunningtoniceras* sp. juv.

Plate 3, figs. 1–7

*Material.* Five specimens, including USNM 423693–423695, from USGS Mesozoic Locality 12650, *Metoicoceras mosbyense* zone.

*Description.* Specimens range from 7 to 12.5 mm in diameter. In the smaller specimens coiling is very involute with a small, deep umbilicus comprising approximately 19% of the diameter. The whorl section is depressed, reniform in intercostal section and polygonal in costal section, with the greatest breadth at the outer ventrolateral tubercles. There are 6–7 strong umbilical bullae per whorl that give rise to broad, blunt primary ribs. The latter weaken at mid-flank and alternate regularly with single secondary ribs that arise at mid-flank. All bear a strong conical inner ventrolateral tubercle that appears to have been the base for a long spine. These ribs broaden and sweep forwards to a strong conical outer ventrolateral tubercle on the mould of the phragmocone; USNM 423693 shows these tubercles to have been the bases of long septate spines (Pl. 3, figs. 1–3). A broad rib passes straight across the venter, and bears a weak siphonal clavus. Shorter, intercalated ribs are also present; some bear only outer ventrolateral and siphonal tubercles, others bear only the siphonal row; there are as many as 18 ventral ribs per whorl.

*Discussion.* Preservation of septate spines on USNM 423693 gives this specimen a quite remarkable appearance (Pl. 3, figs. 1–3). The variable nature of the intercalated ventral ribs shows these tiny specimens to be *Cunningtoniceras* beyond any doubt; see Wright and Kennedy (1987) for a recent review of the genus. The specimens are so tiny that they cannot be usefully compared with any previously described species, although we have seen comparable tiny limonitic nuclei of *Cunningtoniceras* from Upper Cenomanian pelagic clay facies in Tunisia. *Cunningtoniceras* is widespread in the US Western Interior and Gulf Coast regions, with, for instance, *C. inerme* (Pervinquière, 1907) in the *Conlinoceras tarrantense* zone, *C. lonsdalei* (Adkins, 1928) in the *Acanthoceras bellense* zone and *C. johnsonanum* (Stephenson, 1955) in the *Acanthoceras amphibolum* zone of Texas (Kennedy and Cobban, 1990). A range of species in the upper Cenomanian of New Mexico and Arizona includes *C. arizonense* Kirkland and Cobban, 1986 (p. 2, pls. 1–8), of which the present specimens might conceivably be nuclei.

*Occurrence.* As under *Material*.

## Genus TARRANTOCERAS Stephenson, 1955, p. 59

*Type species.* *Tarrantoceras rotatile* Stephenson, 1955, p. 59, pl. 5, figs. 1–10; by original designation = *Mantelliceras sellardsi* Adkins, 1928, p. 239, pl. 25, fig. 1; pl. 26, fig. 1.



*Tarrantoceras cuspidum* (Stephenson, 1953)

Plate 3, figs. 8–12

1953 *Acanthoceras cuspidum* Stephenson, p. 202, pl. 50, figs. 1–4.1990 *Tarrantoceras cuspidum* (Stephenson, 1953); Kennedy and Cobban, p. 134, pl. 14, figs. 21–24, 26–28.

*Types.* Holotype is USNM 105974, by original designation; paratype is USNM 105975, both from gullies south of the old Sherman road, 4.5 km east of Whitesboro, Grayson County, Texas. An unfigured paratype is from USGS Mesozoic locality 14092, a bluff 1.6 km north and 2.9 km east of Sadler, Grayson County, Texas. All are from the Templeton Member of the Woodbine Formation, *Plesiakanthoceras wyomingense* zone.

*Material.* USNM 423697 as well as other specimens from USGS Mesozoic locality 22871, *P. wyomingense* zone. USNM 423696 and other specimens from USGS Mesozoic locality D4466, Upper Cenomanian *Dunveganoceras pondi* zone.

*Discussion.* USNM 423697 is 22 mm in diameter (Pl. 3, figs. 10–12) and differs in no significant respects from the types. USNM 423696 is larger than the types, and shows the same strong ornament persisting to a whorl height of 13 mm (Pl. 3, figs. 8 and 9). The innermost whorls of USNM 423697 are well-exposed. They show feeble umbilical bullae giving rise to low, broad prorsiradiate ribs that terminate in massive inner ventrolateral spines that are housed in notches in the umbilical wall of preceding whorl, as in the types. *I. cuspidum* has not been previously recognized outside Texas, and the present occurrence is of some importance in providing a probable date for the Templeton Member.

*Occurrence.* *Plesiakanthoceras wyomingense* zone of Texas and Montana; *Dunveganoceras pondi* zone of Montana.

## EXPLANATION OF PLATE 3

Figs. 1–7. *Cunningtoniceras* sp. juv. 1–3, USNM 423693; 4, 5, USNM 423694; 6, 7, USNM 423695, from USGS Mesozoic locality 12650, *Metoicoceras mosbyense* zone.

Figs. 8–12. *Tarrantoceras cuspidum* (Stephenson, 1953). 8, 9, USNM 423696; 10–12, USNM 423697, from USGS Mesozoic localities D4466 and 22871, *Dunveganoceras pondi* and *Plesiakanthoceras wyomingense* zones.

Figs. 13–21, 26–31, 35–44. *Kastanoceras spiniger* gen. et sp. nov. 13–15, holotype, USNM 423699; 16–18, paratype USNM 423700; 19–21, paratype USNM 423701; 26–28, paratype USNM 423702; 29–31, paratype USNM 423703; 35–40, paratype USNM 423704; 41–44, paratype USNM 423705, all from USGS Mesozoic locality 22871, *P. wyomingense* zone.

Figs. 22–25. *Tarrantoceras exile* sp. nov. Holotype, USNM 423698, from USGS Mesozoic locality 12650, *Metoicoceras mosbyense* zone.

Figs. 32–34. *Tarrantoceras sellardsi* (Adkins, 1928). USNM 400767, from USGS Mesozoic locality D12626, *Acanthoceras amphibolum* zone.

Figs. 45, 46, 51–56. *Sunitomoceras* spp. juv. 45, 46, USNM 423706; 51, 52, USNM 423707, both from USGS Mesozoic locality 23062, *Sciponoceras gracile* zone. 53–56, USNM 423708, from Mesozoic locality D4628, *S. gracile* zone.

Figs. 47–50, 57–61. *Sunitomoceras conlini* (Wright and Kennedy, 1981). 47–50, USNM 400804, from USGS Mesozoic locality D11529; 57, 58, USNM 400807, from USGS Mesozoic locality D10196; 59–61, USNM 400805, from USGS Mesozoic locality D11529, all *S. gracile* zone.

Figs. 62–64. *Moremanoceras montanaense* sp. nov. Holotype, USNM 423691, from USGS Mesozoic locality D12890, *M. mosbyense* zone.

Figs. 1–3, 6, 7, 13–34, 38–48 are  $\times 2$ ; figs. 4, 5 are  $\times 3$ ; the remainder are  $\times 1$ .



*Tarrantoceras exile* sp. nov.

Plate 3, figs. 22–25

*Derivation of name.* *Exilis* (Latin): slender, thin, pertaining to the whorl section of the species.

*Holotype.* USNM 423698 from USGS Mesozoic locality 12650, *Metoicoceras mosbyense* zone.

*Dimensions*

	<i>D</i>	<i>Wb</i>	<i>Wh</i>	<i>Wb:Wh</i>	<i>U</i>
USNM 423698	12.61 (100)	4.3 (34.1)	5.1 (40.5)	0.84	4.3 (34.1)

*Description.* Coiling evolute, with broad shallow umbilicus comprising 34% of diameter with low, rounded wall that is indented to accommodate the inner ventrolateral tubercles of the preceding whorl (Pl. 3, fig. 23). Whorl section of this specimen is that of a *Tarrantoceras*, as can be seen by comparison with specimens of *T. sellardsi* illustrated for comparison (Pl. 3, figs. 32–34). Coarseness of ornament yet lack of massive inner and outer ventrolateral tubercles immediately distinguish it from *T. cuspidum* (Pl. 3, figs. 8–12) whereas the combination of evolute slender whorls and coarse ornament gives the shell a quite different appearance than any *T. sellardsi* we have seen. It represents the youngest member of the *Tarrantoceras* lineage.

*Occurrence.* As for types.

## Genus KASTANOCERAS nov.

*Derivation of name.* *Kastanos* (Greek); chestnut, from the common spinosity of the new genus and the seed cases of that tree.

*Type species.* *Kastanoceras spiniger* gen. et sp. nov., *Plesiacanthoceras wyomingense* zone of Montana.

*Diagnosis.* Dwarf, presumed microconch adult at 8 mm, largest (incomplete) macroconch is 10 mm in diameter. Coiling evolute, coronate, intercostal section depressed reniform, costal section with flattened sides that converge to an umbilical wall notched to accommodate outer ventrolateral spines of preceding whorl. Flank ribs feeble, prorsiradiate, terminating in large inner ventrolateral spines. Venter with feeble outer ventrolateral and siphonal clavi that decline at smallest diameters visible. Ornament declines markedly on adult body chamber. Suture with broad, little-incised, asymmetrically bifid E/L, narrower L and simple bifid L/U<sub>2</sub>.

*Discussion.* Inner whorls are inseparable from those of *T. cuspidum*, with which *K. spiniger* gen. et sp. nov., occurs (Pl. 3, figs. 13–21). But whereas *T. cuspidum* grows to a diameter of at least 35 mm and has outer whorls with very strong, close-spaced clavi and strong flank ornament at this size, the present specimens show approximation of sutures and decline of body chamber ornament that indicates them to be adult at phragmocone diameters of as little as 7.5 mm in the microconch holotype. *Kastanoceras* is thus a progenic dwarf derivative of *Tarrantoceras* just as *Protacanthoceras* Spath, 1923 is a similarly derived dwarf offshoot of *Acanthoceras* Neumayr, 1875 (Wright and Kennedy, 1980, 1987; Kennedy and Wright, 1985).

*Occurrence.* *P. wyomingense* zone, Montana.

*Kastanoceras spiniger* gen. et sp. nov.

Plate 3, figs. 13–21, 26–31, 35–44

*Types.* Holotype is USNM 423699, paratypes USNM 423700–423705 from USGS Mesozoic locality 22871, *P. wyomingense* zone.

*Diagnosis.* With the characters of the genus.



*Description.* Small, presumed microconch 8 mm diameter, largest, incomplete macroconch has phragmocone diameter of 7.5 mm and total diameter of 10 mm with only 120° of body chamber preserved. Coiling is evolute with the umbilicus comprising 39% of the diameter, deep, with a very low, rounded wall that is notched to accommodate the inner ventrolateral spines of the preceding whorl. Whorl section depressed reniform in intercostal section. In costal section the flanks are concave and diverge outwards, with the greatest breadth at the inner ventrolateral spine; the venter is broadly arched. There are 9–11 feeble umbilical bullae that connect by low, broad prorsiradiate ribs to prominent inner ventrolateral spines that are directed outwards and normal to the median plane of the shell. Feeble outer ventrolateral and siphonal clavi are barely visible at the smallest diameter seen, but they strengthen towards the beginning of the adult body chamber and may be linked by low spiral ridges. Ventral ribbing is feeble or absent; interspaces between rows of ventral tubercles may be deepened and constriction-like. On the adult body chamber all ornament weakens markedly.

*Discussion.* Differences from *T. cuspidum*, from which the species arose pedomorphically, are discussed under the genus.

*Occurrence.* As for types.

Genus SUMITOMOCERAS Matsumoto, 1969, p. 280.

*Type species.* *Sumitomoceras faustum* Matsumoto and Muramoto, 1969, p. 283, pl. 283, pl. 38, figs. 1–4; text-fig. 8, by original designation.

*Sumitomoceras* spp. juv.

Plate 3, figs. 45, 46, 51–56; Plate 4, figs. 57, 58; Plate 6, figs. 32–35

*Material.* USNM 423706 and 423707 from USGS Mesozoic locality 23062; USNM 423708 from USGS Mesozoic locality D4628; USNM 423731 from USGS Mesozoic locality D5780; USNM 423747, from USGS Mesozoic locality D12052; all Upper Cenomanian *Sciponoceras gracile* zone.

*Description.* USNM 423706 is only 7.5 mm in diameter. Coiling is evolute, with  $U = 27\%$  of diameter, with a low, subvertical wall and narrowly rounded umbilical shoulder. The whorl section is compressed with subparallel flanks, broadly rounded ventrolateral shoulders and an arched venter in intercostal section, the costal section is polygonal. Primary ribs arise from feeble bullae perched on the umbilical shoulder. They are narrow and prorsiradiate and separated by 1 or 2 shorter intercalated ribs. All ribs bear small conical inner ventrolateral tubercles. A strong rib sweeps forward across the ventrolateral shoulder to an outer ventrolateral clavus. Scarcely visible at the smallest diameter visible, this rib becomes more prominent as size increases. USNM 423707 shows similar ornament at the smallest diameter visible, but is 18 mm in diameter (Pl. 3, figs. 51, 52), and shows both inner and outer ventrolateral tubercles declining. In USNM 423706 some of the interspaces are distinctly deepened and constriction-like. USNM 423708 is 15.7 mm in diameter, has weak or no umbilical bullae, very weak ornament on the inner flanks, but prominent inner ventrolateral tubercles throughout, and no, or incipient outer ventrolaterals. USNM 423747 (Pl. 6, figs. 32–35) has a maximum preserved diameter of 22.5 mm. Coiling is very evolute, with a broad shallow umbilicus comprising 23% of diameter. Whorl section is compressed, with flattened subparallel flanks and broadly rounded venter. Flank ornament consists of low, crowded ribs, 18 per half whorl, of which eight arise at incipient umbilical bullae, the remainder intercalating. Ribs are flexuous and prorsiradiate, convex across the inner mid-flank, thereafter concave and strengthening, crossing the venter in a shallow convexity. There are feeble rounded inner ventrolateral and clavate outer ventrolateral and siphonal tubercles at the smallest diameter visible. The inner ventrolateral tubercles efface as size increases but feeble outer ventrolateral and siphonal tubercles persist to the largest diameter seen. Suture with broad, symmetrically bifid E/L, smaller bifid L, little incised L/U<sub>2</sub> and small U.

*Discussion.* The identity of these specimens is demonstrated by comparison with an ontogenetic series of *S. conlini* (Wright and Kennedy, 1981) from the *S. gracile* zone in New Mexico (Pl. 3, figs. 47–50, 57–61). The smallest, USNM 400804, can be linked to USNM 400805 which shows very early loss of all tuberculation and is presumed to be a microconch (Pl. 3, figs. 59–61); in others, the tubercles persist to a much greater size (USNM 400807: Pl. 3, figs. 57 and 58).

*Occurrence.* As for material.

## Genus ALZADITES nov.

*Derivation of name.* From the town of Alzada, Carter County, Montana, 9.7 km southeast of the type locality.

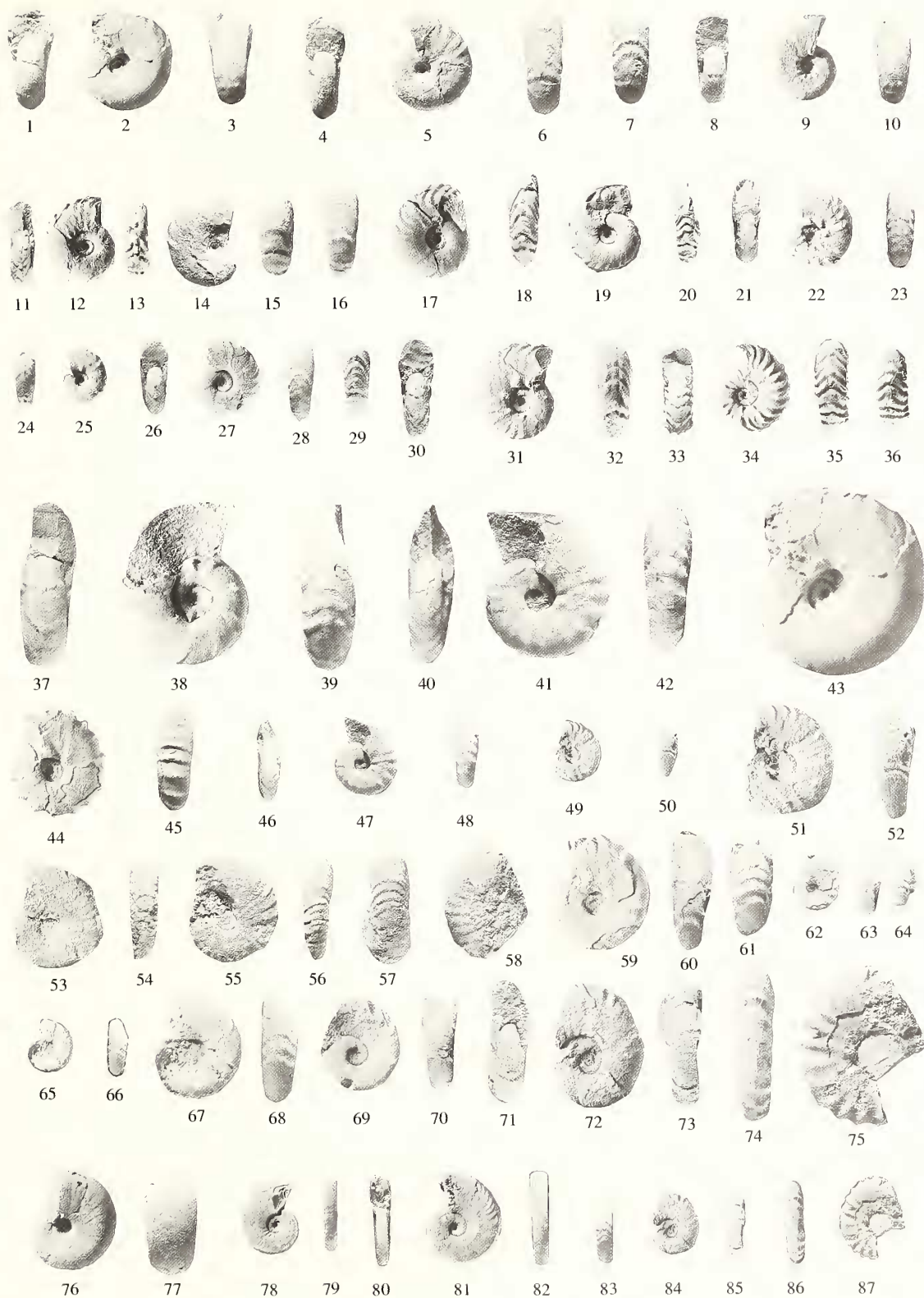
*Type species.* *Alzadites alzadensis* gen. et sp. nov., *Plesiacanthoceras wyomingense* zone, Montana.

*Diagnosis.* Small, adult at 16.5 mm or less in diameter. Involute with small umbilicus, whorl section compressed with flattened subparallel flanks and rounded venter. Phragmocone with tiny, distant umbilical bullae, distant prorsiradiate ribs and feeble to strong inner ventrolateral tubercles plus outer ventrolateral and siphonal clavi. Ventral ribbing strengthens on adult body chamber and tubercles decline, leaving strong, coarse, prorsiradiate, concave ribs on outer flank that cross venter in a broad convexity, or a chevron, separated by broad interspaces. Constrictions may develop on internal moulds of phragmocone and body chamber. Suture with simple, little-incised elements; E/L broad, and symmetrically bifid, L narrow, shallow, bifid, saddles on umbilical lobe simple, bifid.

*Discussion.* *Alzadites* most closely resembles certain *Protacanthoceras* Spath, 1923, and the type species is homeomorphic with *P. asgeirri* Wright and Kennedy, 1980 (p. 90, figs. 20–21, 47). This is scarcely surprising inasmuch as both are interpreted as progenic dwarfs and as a result share certain features that are common to most acanthoceratine nuclei. *Protacanthoceras* derives from *Acanthoceras* Neumayr, 1875, and the type species, *Ammonites bunburianus* Sharpe, 1853 (p. 25, pl. 9, fig. 3; see Wright and Kennedy, 1980, p. 91, figs. 29–33, 41–43, 48; 1987, p. 215, pl. 55, figs. 10–16; text-figs. 83B, C) and many of the other early *Protacanthoceras* species are easily differentiated from

## EXPLANATION OF PLATE 4

- Figs. 1–10, 14–16, 43. *Alzadites alzadensis* gen. et sp. nov. 1–3, 43, paratype USNM 423710; 4–7, holotype USNM 423709; 8–10, paratype USNM 423712; 14–16, paratype USNM 423711, all from USGS Mesozoic locality 22871, *Plesiacanthoceras wyomingense* zone.
- Figs. 11–13, 17–39. *Alzadites westonensis* gen. et sp. nov. 11–13, paratype USNM 423715; 17, 18, paratype USNM 423716; 19, 20, paratype USNM 423717; 21–23, paratype USNM 423718; 24, 25, paratype USNM 423719; 26–29, paratype USNM 423720; 30–32, paratype USNM 423721; 33–36, holotype USNM 423714; 37–39, paratype USNM 423722, all from USGS Mesozoic locality D5947, *Dunveganoceras pondi* zone.
- Figs. 40–42, 46–48. *Alzadites incompitus* gen. et sp. nov. Paratype USNM 423728, from USGS Mesozoic locality D5249, *Sciponoceras gracile* zone.
- Figs. 44, 45. *Alzadites?* sp. USNM 423730, from USGS Mesozoic locality D5947, *D. pondi* zone.
- Figs. 49–52, 65–70. *Microsulcatoceras puzosiiforme* gen. et sp. nov. 49–52, holotype, USNM 423734; 65–68, paratype USNM 423735; 69, 70, paratype USNM 423736, all from USGS Mesozoic locality 23062, *S. gracile* zone.
- Figs. 53–56. *Alzadites* sp. A. 53–54, USNM 423732; 55–56, USNM 423733; from USGS Mesozoic locality D5780, *S. gracile* zone.
- Figs. 57, 58. *Sumitomoceras* sp. juv. USNM 423731, from USGS Mesozoic locality D5780.
- Figs. 59–64. *Microsulcatoceras texanum* gen. et sp. nov. Holotype USNM 423739 from stream bank 2.4 to 2.9 km southwest of Britton, on and east of Rogers Farm, Ellis County, Texas. Britton Formation, *S. gracile* zone.
- Figs. 71–73, 84, 85. *Microsulcatoceras?* sp. USNM 423740, from USGS Mesozoic locality D11514, *Neocardioceras juddii* zone.
- Figs. 74, 75, 86, 87. *Microsulcatoceras crassum* gen. et sp. nov. Holotype, USNM 423737, from USGS Mesozoic locality D4682, *S. gracile* zone. Figs. 76, 77. *Morenanoceras costatum* Cobban, Hook and Kennedy, 1989. USNM 423738, from USGS Mesozoic locality D5947, *D. pondi* zone.
- Figs. 78–83. *Borissiakoceras orbiculatum* Stephenson, 1955. 78, 79 are USNM 423663, from USGS Mesozoic locality D5947; 80–83 are USNM 423664 from USGS Mesozoic locality D4462, all from *D. pondi* zone.
- Figs. 37–45, 51, 52, 59–61, 67–77 are  $\times 2$ ; the remainder are  $\times 1$ .





*Alzadites* by their polygonal costal whorl section, coarse ribbing and tuberculation which persists to the body chamber. Only the later *Protacanthoceras* species that are progenically derived from other, already diminutive species of the genus come to resemble *Alzadites*.

The evolutionary origin of *Alzadites* lies in some upper Cenomanian acanthoceratine of the US Western Interior lineages, rather than in Old World *Acanthoceras*. There is a marked similarity between the smooth, distantly and feebly ribbed and tuberculate phragmocones of *Alzadites* and the early whorls of certain *Tarrantoceras* Stephenson, 1955 (e.g. Pl. 4, figs. 32 and 33) although these generally have stronger inner ventrolateral tubercles than in the type species of *Alzadites* (Pl. 4, figs. 1–10, 14, 15, 17, 43), more closely resembling the inner whorls of *A. westonensis* gen. et sp. nov. (Pl. 4, figs. 8–39).

*Occurrence.* *Plesiacanthoceras wyomingense* zone of Montana and Wyoming. Upper Cenomanian *Sciponoceras gracile* zone of Utah.

*Alzadites alzadensis* gen. et sp. nov.

Plate 4, figs. 1–10, 14–16, 43

*Types.* Holotype is USNM 423709, paratypes USNM 423710 to 423712; three unfigured paratypes USNM 423713, all from USGS Mesozoic locality 22871, *P. wyomingense* zone.

*Dimensions.*

	<i>D</i>	<i>Wb</i>	<i>Wh</i>	<i>Wb:Wh</i>	<i>U</i>
USNM 423710	16.0 (100)	5.6 (35.0)	7.4 (46.3)	0.76	2.9 (18.1)
USNM 423709	16.6 (100)	6.5 (39.2)	9.5 (57.2)	0.68	2.4 (14.5)
at	14.2 (100)	5.7 (40.1)	7.2 (50.7)	0.79	1.7 (12.0)
USNM 423711	15.6 (100)	6.4 (41.0)	8.3 (53.2)	0.77	2.1 (13.5)
USNM 423712	13.4 (100)	5.7 (42.5)	6.7 (50.0)	0.85	1.7 (12.7)

*Diagnosis.* *Alzadites* with coarse, blunt ribs on body chamber, where tubercles decline and ultimately disappear.

*Description.* Coiling involute with small, shallow umbilicus. Umbilical wall low, umbilical shoulder narrowly rounded. Whorl section compressed, with flattened, subparallel flanks, ventrolateral shoulders and venter broadly and evenly rounded. Phragmocone very feebly ornamented. In the best preserved specimen, up to 11 feeble umbilical bullae give rise to low, narrow, prorsiradiate, distant ribs that efface at mid-flank (Pl. 4, figs. 8–10); feeble intercalated ribs are also present. Most if not all ribs bear a feeble inner ventrolateral tubercle. The ribs efface over the venter, where there are outer ventrolateral and siphonal clavi (Pl. 4, figs. 8 and 10). On the adult body chamber, outer flank and ventral ribbing strengthens and coarsens markedly; the ribs are concave on the outer flank and cross the venter in a broad convexity. The ribs bear outer ventrolateral and siphonal clavi at the beginning of the body chamber, but these progressively efface and disappear. The interspaces between ribs are broad and some are deepened into constrictions. There is a great variation in the strength and visibility of ornament, especially on phragmocones.

Suture simple, as for genus.

*Discussion.* *A. alzadensis* gen. et sp. nov., differs from *A. westonensis* gen. et sp. nov., in the following respects: it is larger, the inner ventrolateral tubercles are much weaker, the body chamber ribbing blunt and restricted to the outer flank whereas that of *A. westonensis* extends to the umbilical seam, is markedly flexuous and sharper, with a pronounced acute ventral chevron and persistent tubercles.

*Occurrence.* As for types.

*Alzadites westonensis* sp. nov.

Plate 4, figs. 11–13, 17–39

*Derivation of name.* From Weston County, Wyoming, where the types were found.

*Types.* Holotype is USNM 423714, paratypes are USNM 423715 to 423723, 12 unfigured paratypes are USNM 423724, all from USGS Mesozoic locality D5947, *Dunveganoceras pondi* zone.

*Diagnosis.* *Alzadites* with variable, generally strong ribs that arise singly or in pairs from umbilical bullae or intercalate. The ribs are flexuous, with persistent inner ventrolateral tubercles. Outer ventrolateral and siphonal clavi are borne on chevron ribs that persist to the adult body chamber.

*Description.* Small, adults 15 mm or less in diameter. Coiling involute with small shallow umbilicus, umbilical wall low, rounded, umbilical shoulder narrowly rounded. Whorl section compressed with subparallel flanks and rounded venter in intercostal section; costal section polygonal with greatest breadth at inner ventrolateral tubercle; venter fastigate. Phragmocone ornament varies from weak to strong. There are thus weak to strong umbilical bullae that give rise to pairs of weak to strong ribs, either singly or in pairs, with occasional intercalated ribs to give a total rib density of around 11 ribs per half whorl in robustly ornamented individuals. The ribs are prorsiradiate and flexuous, and bear weak to strong, conical, inner ventrolateral tubercles that are housed in notches in the umbilical wall of the succeeding whorl (Pl. 4, fig. 38). The ribs sweep forward over the ventrolateral shoulders to clavate inner ventrolateral clavi, linked to turn to strong siphonal clavi at the apex of an acute chevron. This ornament persists onto the adult body chamber. Towards the mature aperture umbilical and ventrolateral tubercles decline first. The adult aperture is preceded by a few crowded ribs that are restricted to the outer flank and venter and lack tubercles. There is a pronounced ventral lappet (Pl. 4, fig. 34).

Suture simple, as for genus.

*Discussion.* Differences from *A. alzadensis* gen. et sp. nov., are discussed under that species.

*Occurrence.* As for types.

*Alzadites incomptus* gen. et sp. nov.

Plate 4, figs. 40–42, 46–48; Plate 6, figs. 1–22

*Derivation of name.* *Incomptus* (Latin): unadorned.

*Types.* Holotype is USNM 423725, from USGS Mesozoic locality D12052 as are figured paratypes USNM 423726 and 423727; paratype USNM 423728 is from USGS Mesozoic locality D5249, SE $\frac{1}{4}$  sec. 12, T. 43 S., R. 2 E., Kane County, Utah, Tropic Shale, 9.1–10.7 m (30–35 feet) above base; unfigured paratype USNM 423729 is from USGS Mesozoic locality D5255, NE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 32, T. 41, S., R. 7 E., Kane County, Utah, Tropic Shale 4.6–9.2 m (15–30 feet) above base. All *Sciponoceras gracile* zone.

*Diagnosis.* Small, adult at 12 mm diameter. Phragmocone smooth to feebly to strongly ribbed with blunt umbilical bullae and feeble inner and outer ventrolateral tubercles, interspaces sometimes deepened into constrictions. Tubercles decline on adult body chamber, which is ornamented by delicate prorsiradiate ribs and may be constricted.

*Description.* The type specimens are rather variable (Pl. 6, figs. 1–22). Coiling is involute, with a small umbilicus, comprising 21–24% of diameter in adults, shallow, with a low, flattened wall and narrowly rounded umbilical shoulder. The whorl section is compressed, with flattened subparallel sides and a rounded venter. Phragmocones vary from smooth (Pl. 6, figs. 10–12) to those with weak umbilical bullae, up to nine per whorl. These give rise to low, blunt, prorsiradiate ribs, singly or in pairs, while shorter, intercalated ribs arise around mid-flank. The ribs are feebly flexed, and strengthen across the flank, crossing the venter in a broad convexity. Interspaces are sometimes deepened into constrictions. Tuberculation is poorly developed, but the most coarsely ribbed individuals develop indications of inner and outer ventrolateral and siphonal tubercles on some ribs. This general style of ornament persists on to the beginning of the adult body chamber, the last part of which is characterized by delicate, flexuous flank ribs that strengthen over the ventrolateral shoulder and venter, are concave on the former and cross the latter in a broad convexity.

Suture with little-divided elements; E narrow, E/L broad and bifid, L shallow and bifid.

*Discussion.* Weakness of ornament, notably tubercles, plus pattern of ribbing immediately distinguish this species from *A. westonensis* gen. et sp. nov., described above. *A. alzadensis* gen. et sp. nov., is more similar, but has a broader, larger shell with coarser ribbing on the adult body chamber.

*Occurrence.* As for types.

*Alzadites?* sp.

Plate 4, figs. 44, 45

*Material.* USNM 423730 from USGS Mesozoic locality D5947, *Dunveganoceras pondi* zone.

*Description.* Specimen is a phragmocone retaining traces of the original aragonitic shell and is 8.2 mm in diameter. Coiling is involute with  $U = 22\%$  of diameter, the umbilical wall low, the umbilical shoulder narrowly rounded. The whorl section is compressed, with flattened subparallel flanks and a rounded venter in intercostal section. Ribs, which number eight per half whorl, are weak and prorsiradiate on the flank but strengthen markedly on the venter where they are high and flared with flattened tops. Occasional unflared intercalated ribs are present. Sutures not seen.

*Discussion.* We believe this specimen to be pathological. It is slightly asymmetrical in ventral view (Pl. 4, fig. 45), and resembles symmetrical malformed specimens such as *Ammonites salteri* of Sharpe, 1857 (pl. 23, figs. 3 and 5).

Of species present in the same concretion the general shell morphology most closely resembles that of *A. westonense* gen. et sp. nov.

*Occurrence.* As for material.

*Alzadites* sp. A.

Plate 4, figs. 53–56

*Material.* USNM 423732 and 423733 from USGS Mesozoic locality D5780, NE $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 8, T. 5 S., R. 2 E., Socorro County, New Mexico. Lower part of Mancos Shale, Bridge Creek Limestone Beds, second limestone from base. *Sciponoceras gracile* zone.

*Description.* The largest complete specimen is 18 mm in diameter. All are crushed, with consequent effacement of ornament. In USNM 423732 (Pl. 4, figs. 53–56) the phragmocone is smooth, in USNM 423733 (Pl. 4, figs. 53 and 54) feeble bullae give rise to prorsiradiate primary ribs with shorter intercalated secondaries between, all ribs strengthening over the venter. All specimens show persistent ribbing on the body chamber, with some interspaces deepened and constriction-like.

*Discussion.* Such of the ornament as is visible recalls that of *A. incomptus* gen. et sp. nov., but poor preservation precludes positive determination.

*Occurrence.* As for material.

#### Genus *MICROSULCATOCERAS* nov.

*Derivation of name.* Mikros (Greek), small; *sulcus* (Latin), groove, pertaining to the size and ornament of the shell.

*Type species.* *Microsulcatoceras puzosiiforme* gen. et sp. nov., *Sciponoceras gracile* zone of Montana.

*Diagnosis.* Small, adult at 10 mm or less. Compressed, with flattened subparallel sides and rounded venter. On phragmocone distant umbilical bullae give rise to prorsiradiate, straight, primary ribs that terminate in conical inner ventrolateral tubercles. These tubercles link over the venter via a low,



convex rib, followed by a broad, shallow constriction. Tubercles decline on adult body chamber where constrictions strengthen and are flanked by flexuous, prorsiradiate, collar ribs. Sutures unknown.

*Discussion.* This diminutive genus is quite unlike any other described micromorph. At first sight the presence of flexuous constrictions is suggestive of the superfamily Desmocerataceae Zittel, 1895, notably certain Puzosiinae. The presence of tubercles at such a small size is not, however, a feature of this group (although they may develop at maturity). Instead, we believe the affinities of *Microsulcatoceras* may lie in certain Acanthoceratinae. There is a marked resemblance of the innermost whorls of the *Sumitomoceras* from the *gracile* zone described above to the inner whorls of the new genus (compare Pl. 3, figs. 43–56 and Pl. 4, figs. 59–75): both have prominent umbilical and inner ventrolateral tubercles, but *Microsulcatoceras* lacks the outer, having instead a ventral rib that, although accentuated at the outer ventrolateral position, does not differentiate into a distinct tubercle. Both lack a siphonal tubercle, while certain adult *Sumitomoceras*, including the type, develop deepened, constricted interspaces between the ribs. On the balance of the evidence, we are inclined to regard *Microsulcatoceras* as a progenic dwarf derivative of *Sumitomoceras*.

*Occurrence.* *Sciponoceras gracile* zone of Montana, Texas, and possibly New Mexico.

*Microsulcatoceras puzosiiforme* gen. et sp. nov.

Plate 4, figs. 49–52, 65–70

*Derivation of name.* Puzosiiforme – Puzosia-like, from the superficial resemblance to certain *Puzosia* Bayle, 1878.

*Types.* Holotype is USNM 423734, paratypes USNM 423735 and 423736, from USGS locality 23062, *S. gracile* zone.

*Diagnosis.* *Microsulcatoceras* with delicately ribbed and constricted body chamber.

*Description.* Small, adult at 9.5 mm. Coiling evolute with small, shallow umbilicus; umbilical wall low, flattened, umbilical shoulder narrowly rounded. Whorl section compressed with flattened, subparallel flanks and broadly rounded venter. Phragmocone has tiny distant umbilical bullae, 8 per whorl, that give rise to low, prorsiradiate ribs that terminate in blunt inner ventrolateral tubercles linked over the venter by a broad, convex rib. Intercalated ribs with feeble to obsolete inner ventrolateral tubercles are occasionally present. The ribs are succeeded by broad, shallow constrictions, most obvious on the outer flank and over the venter. Tubercles decline on the adult body chamber and constrictions strengthen, extending down to the umbilical wall. The constrictions are prorsiradiate, markedly concave on the outer flank, and slightly flexuous; they are bordered by collar ribs and cross the venter in a broad convexity. Interspaces bear shorter intercalated ribs, most prominent just before the adult aperture.

Sutures not seen.

*Discussion.* *M. puzosiiforme* gen. et sp. nov., is easily differentiated from *M. crassum* and *M. texanum* gen. et spp. nov., by its delicate body chamber ornament and clearly differentiated constrictions, rather than the coarse decoration of the latter, where constrictions are less well differentiated and umbilical bullae persist.

*Occurrence.* As for types.

*Microsulcatoceras crassum* gen. et sp. nov.

Plate 4, figs. 74, 75, 86, 87

*Derivation of name.* *Crassus* (Latin): thick, referring to the body chamber ornament.

*Types.* Holotype is USNM 423737, from USGS Mesozoic locality D4628, NW $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 11, T. 43. S., R. 2 E., Kane County, Utah, Tropic Shale, from concretions 3 m (10 feet) above base. *Sciponoceras gracile* zone.

*Diagnosis.* *Microsulcatoceras* with coarse body chamber ornament and persistent umbilical bullae.

*Description.* Holotype and only known specimen is 13 mm in diameter. Umbilicus small, 33 % of diameter. Whorl section compressed with flattened subparallel flanks and rounded venter. Blunt umbilical bullae give rise to pairs of flexuous prorsiradiate coarse ribs, with occasional shorter, intercalated ribs. All ribs are concave and strengthen markedly on the outer flanks and venter which they cross in a broad convexity. Inner flank ribs decline in strength on the last part of the specimen and ventral ribbing crowds, suggesting it to be adult. Some interspaces are slightly deepened.

*Discussion.* Coarseness of ornament and persistence of bullae onto the body chamber immediately distinguish this species from *M. puzosiiforme*.

*Occurrence.* As for type.

*Microsulcatoceras texanum* gen. et sp. nov.

Plate 4, figs. 59–64

*Type.* USNM 423739 from stream bank 2.4 to 2.9 km southwest of Britton, on and east of the Rogers Farm, Ellis County, Texas, Eagle Ford Group, Britton Formation, *Sciponoceras gracile* zone, ex J. P. Conlin collection.

*Diagnosis.* Small, adult at 9.5 mm diameter. Phragmocone and early body chamber with distant, feebly bullate primary ribs with strong ventrolateral tubercles linked over the venter by a strong convex rib, and occasional prominent constrictions. Last part of body chamber loses tubercles and develops strong, crowded ventrolateral and ventral ribs.

*Discussion.* The phragmocone ribbing and tuberculation are much stronger than in *M. puzosiiforme*, and persist onto the body chamber; the coarsely ribbed venter immediately preceding the adult aperture is equally distinctive. These features of the body chamber also distinguish the species from *M. crassum* gen. et sp. nov.

*Occurrence.* As for type.

*Microsulcatoceras* sp. ?

Plate 4, figs. 71, 72, 73, 84, 85

*Material.* USNM 423740 from USGS Mesozoic locality D11514, Slate Creek in the NW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 36, T. 17 S., R. 18 W., Grant County, New Mexico. Colorado Formation, 9–12 m above flaggy member, *Neocardioceras juddii* zone.

*Discussion.* This badly preserved specimen is 9.5 mm in diameter. Features suggesting it might possibly be a late species of *Microsulcatoceras* are the presence of periodic constrictions and associated collar ribs on a compressed, flat sided shell, although the ventrolateral tubercles typical of juvenile *Microsulcatoceras* are lacking. It might also possibly be a poorly preserved *Sumitomoceras* or *Pseudocalycoceras*.

*Occurrence.* As for material.

Genus PLESIACANTHOCERAS Haas, 1964

(= *Paracanthoceras* Haas, 1963, p. 2; non Furon, 1935, p. 59)

*Type species.* By original designation: *Metoicoceras wyomingense* Reagan, 1924, p. 181, pl. 19, figs. 1 and 2.

*Plesiacanthoceras* cf. *bellsanum* (Stephenson, 1953)

Plate 6, figs. 26–28

- 1953 *Mammites bellsanus* Stephenson, p. 204 (*pars.*), pl. 49, fig. 3; pl. 51, figs. 8–11.  
1971 *Mammites? bellsanus* Stephenson; Kennedy, p. 122.  
1990 *Plesiacanthoceras bellsanum* (Stephenson, 1953); Kennedy and Cobban, p. 135, pl. 2, figs. 5–8; pl. 12, fig. 9; test-fig. 23c.

*Types.* The holotype is USNM 105983, paratypes are USNM 105984–6, from the Templeton Member of the Woodbine Formation on a branch of Cornelius Creek, 4.3 km north 50° east of Bells, Grayson County, Texas. One of the syntypes, USNM 105986, is a *Metoicoceras latoventer* Stephenson, 1953. *Plesiacanthoceras wyomingense* zone.

*Material.* USNM 423741 from USGS Mesozoic locality D5947, *Dunveganoceras pondi* zone.

*Discussion.* *Mammites? bellsanus* is a *Plesiacanthoceras* as discussed by Cobban (1987b) and Kennedy and Cobban (1990). One of the syntypes (Stephenson 1953, pl. 51, fig. 11) has smooth, non-tuberculate innermost whorls. A specimen from USGS Mesozoic locality D5974 also has a smooth nucleus, preceding a strongly ribbed and tuberculate stage that confirm this distinctive ontogenetic development. USNM 423741 has only the faintest traces of ornament to a whorl height of 6 mm. Coiling is very involute with a tiny, deep, conical umbilicus. The whorl section is depressed with flattened, subparallel flanks and a broadly rounded venter; the only decoration is prorsiradiate growth lines. Ornament appears abruptly after this smooth stage. Small umbilical bullae give rise to narrow, straight, prorsiradiate ribs, singly or in pairs, with shorter intercalated ribs. All ribs bear well-developed, conical, inner ventrolateral tubercles, linked by a broad, blunt, prorsiradiate rib to prominent outer ventrolateral clavi. A low, broad, transverse rib links these to a very weak siphonal clavus. When compared to *P. wyomingense* of comparable size (Pl. 6, figs. 36 and 37) the only significant difference is the presence of tubercles in *P. wyomingense* at a stage where *P. bellsanum* is still smooth (compare Pl. 6, figs. 52–54 and Pl. 6, figs. 26–28).

*Occurrence.* *Plesiacanthoceras wyomingense* zone of north-central Texas and, possibly, *Dunveganoceras pondi* zone of Wyoming.

## Genus DUNVEGANOCERAS Warren and Stelck, 1940

*Type species.* *Acanthoceras albertense* Warren, 1930, p. 21, pl. 1, figs. 1, 2; by original designation.

*Dunveganoceras pondi* Haas, 1949

Plate 5, figs. 1–5; Plate 6, figs. 43–51

- 1949 *Dunveganoceras pondi* Haas, p. 22, pl. 8, figs. 1–5, 8; pl. 9, figs. 1, 3, 4; pls. 10–14; text-figs. 11–13, 16, 17.  
1979 *Dunveganoceras pondi* Haas; Merewether, Cobban and Cavanaugh, pl. 4.  
1983 *Dunveganoceras pondi* Haas; Cobban, p. 12, pl. 15, fig. 1.

*Types.* Holotype is AMNH 26416, the original of Haas 1949, pl. 8, fig. 1, pl. 9 figs. 1, 4; Haas mentions 28 specimens that are presumed to be paratypes, all from the basal part of the Cody Shale near Greybull, Wyoming, *Dunveganoceras pondi* zone.

*Material.* USNM 423742 to 423746 from USGS Mesozoic locality D4466, *Dunveganoceras pondi* zone.

*Description.* *D. pondi* is a very large species reaching a diameter in excess of 400 mm. It differs from other species of the genus when adult by virtue of having ribs that are depressed over the mid-line of the venter on the mature body chamber. The early whorls are rather poorly known from Haas' original work, but the present series of specimens reveals previously unknown details. The smallest specimen referred to the species is USNM



423744 (Pl. 6, figs. 43–45), only 5 mm in diameter. The shell is globose and highly involute with a depressed, reniform whorl section. The only ornament is distant radial flank ribs, 4 per half whorl, terminating in strong conical inner ventrolateral tubercles. There is no ventral ornament at this small diameter. USNM 423745 is 15 mm in diameter (Pl. 6, figs. 46–48). Coiling is very involute, with a tiny, deep umbilicus and a depressed reniform intercostal whorl section. At the smallest diameter seen the ornament is weak, but strengthens rapidly to give a depressed polygonal costal section. There are 9–10 prorsiradiate primary ribs per whorl that may or may not arise at feeble umbilical bullae and alternate irregularly with shorter intercalated ribs to give a total of 9–10 ribs per half whorl. All ribs bear strong, conical, inner ventrolateral tubercles. A broad blunt rib projects slightly forward to strong, clavate, outer ventrolateral tubercles, linked across the venter by a low, broad, transverse rib. At the smallest diameter visible there is a low siphonal ridge, beyond there is only a faint trace of siphonal clavi. USNM 423746 (Pl. 6, figs. 49–51) is 22 mm in diameter, the coastal whorl section polygonal and depressed, with a whorl breadth to height ratio of 0.86. There are approximately 14–15 coarse ribs on the outer whorl, with umbilical, inner, and outer ventrolateral tubercles as already described; feeble siphonal tubercles are present throughout. USNM 423742 (Pl. 5, figs. 1–3) is 47 mm in diameter, with the following proportions: Wb: 43.6; Wh: 53.4; Wb:Wh: 0.82; U:14.2. There are 17 ribs on the outer whorl corresponding to 8 umbilical bullae that decline markedly as size increases and from which the ribs arise singly or in pairs, with occasional intercalated ribs. Conical inner and clavate outer ventrolateral tubercles are present, but there is no trace of a siphonal row. USNM 423743 (Pl. 5, figs. 4, 5), a fragment with a maximum preserved whorl height of 30 mm, shows a change to clavate inner ventrolateral tubercles and has a pronounced siphonal ridge, accentuated between the outer ventrolateral clavi.

*Discussion.* The style of ribbing and tuberculation, asymmetry of outer ventrolateral clavi, siphonal ridge and transient siphonal tubercles are all features shared by *Dunveganoceras pondi* and *Plesiocanthoceras wyomingense* of similar size (compare Pl. 6, figs. 36–51 and Pl. 6, figs. 52–54), and there can be little doubt that the former genus gave rise to the latter.

*Occurrence.* *D. pondi* zone of Wyoming, Montana, Iowa and, possibly, South Dakota, Kansas and Colorado.

Subfamily MAMMITINAE Hyatt, 1900, p. 588  
(= Buchiceratinae Hyatt, 1903, p. 26; Metoicoceratidae Hyatt, 1903,  
p. 115; Fallotitinae Wiedmann, 1960, p. 741)  
Genus METOICOCERAS Hyatt, 1903, p. 115

*Type species.* By subsequent designation by Shimer and Shrock, 1944, p. 591: *Ammonites swallowi* Shumard, 1860, p. 591.

### *Metoicoceras* sp. A

Plate 5, figs. 10–12, 17–22

*Types.* Figured specimens USNM 423748–423752, from the Belle Fourche Shale at USGS Mesozoic locality D5947 in Weston County, Wyoming.

### EXPLANATION OF PLATE 5

Figs. 1–5. *Dunveganoceras pondi* Haas, 1949. 1–3, USNM 423742; 4, 5, USNM 423743, from USGS Mesozoic locality D4466, *D. pondi* zone.  
Figs. 6–9. *Metoicoceras* aff. *praecox* Haas, 1949. 6, 7, USNM 423753; 8, 9, USNM 423754, from USGS Mesozoic locality D4462, *D. pondi* zone.  
Figs. 10–12, 17–22. *Metoicoceras* sp. A. 10–12, USNM 423748; 17–19, USNM 423749; 20–22, USNM 423750, all from USGS Mesozoic locality D5947, *D. pondi* zone.  
Figs. 13–16, 23–38. *Metoicoceras mosbyense* Cobban, 1953. 13–16, USNM 423757; 23–25, USNM 423758; 26, 27, USNM 423759; 28–30, USNM 423760; 31, 32, USNM 423761; 33, 34, USNM 423762; 35, 36, USNM 423763; 37, 38, USNM 423764, all from USGS Mesozoic locality D8314, *M. mosbyense* zone.  
Figs. 16, 28, 29 are  $\times 2$ ; fig. 30 is  $\times 3$ ; the remainder are  $\times 1$ .



KENNEDY and COBBAN, *Dunveganoceras* and *Metoicoceras*

*Material.* Five well-preserved, uncrushed specimens from a limestone concretion. Much of the shell material is retained.

*Dimensions* (costal)

	<i>D</i>	<i>Wb</i>	<i>Wh</i>	<i>Wb:Wh</i>	<i>U</i>
USNM 423748	24.3 (100)	12.6 (51.9)	12.5 (51.4)	1.0	3.4 (14.0)
USNM 423750	25.3 (100)	12.2 (48.2)	14.4 (56.9)	0.85	2.5 (10.0)
USNM 423749	32.7 (100)	15.7 (48.0)	16.3 (49.8)	0.96	6.4 (19.6)

*Description.* Coiling involute with small umbilicus of moderate depth. Umbilical wall flattened, umbilical shoulder broadly rounded. Intercoastal whorl section oval with greatest breadth low on the flanks. Costal section with greatest breadth at umbilical bullae, whorl breadth to height ratio 0.85–1.0, with rounded, convergent flanks and venter concave between outer ventrolateral clavi. There are 20–22 ribs per whorl between 14 and 35 mm diameter. Primary ribs arise at the umbilical seam and may or may not develop from umbilical bullae, from which ribs arise singly or in pairs; intercalated ribs arise around mid-flank. Conical inner ventrolateral tubercles are present at the smallest diameters visible but are lost by 18 mm diameter in larger specimens. All ribs bear strong outer ventrolateral clavi, linked across the venter by a strong transverse rib. A weak siphonal tubercle is present to as much as 25 mm diameter.

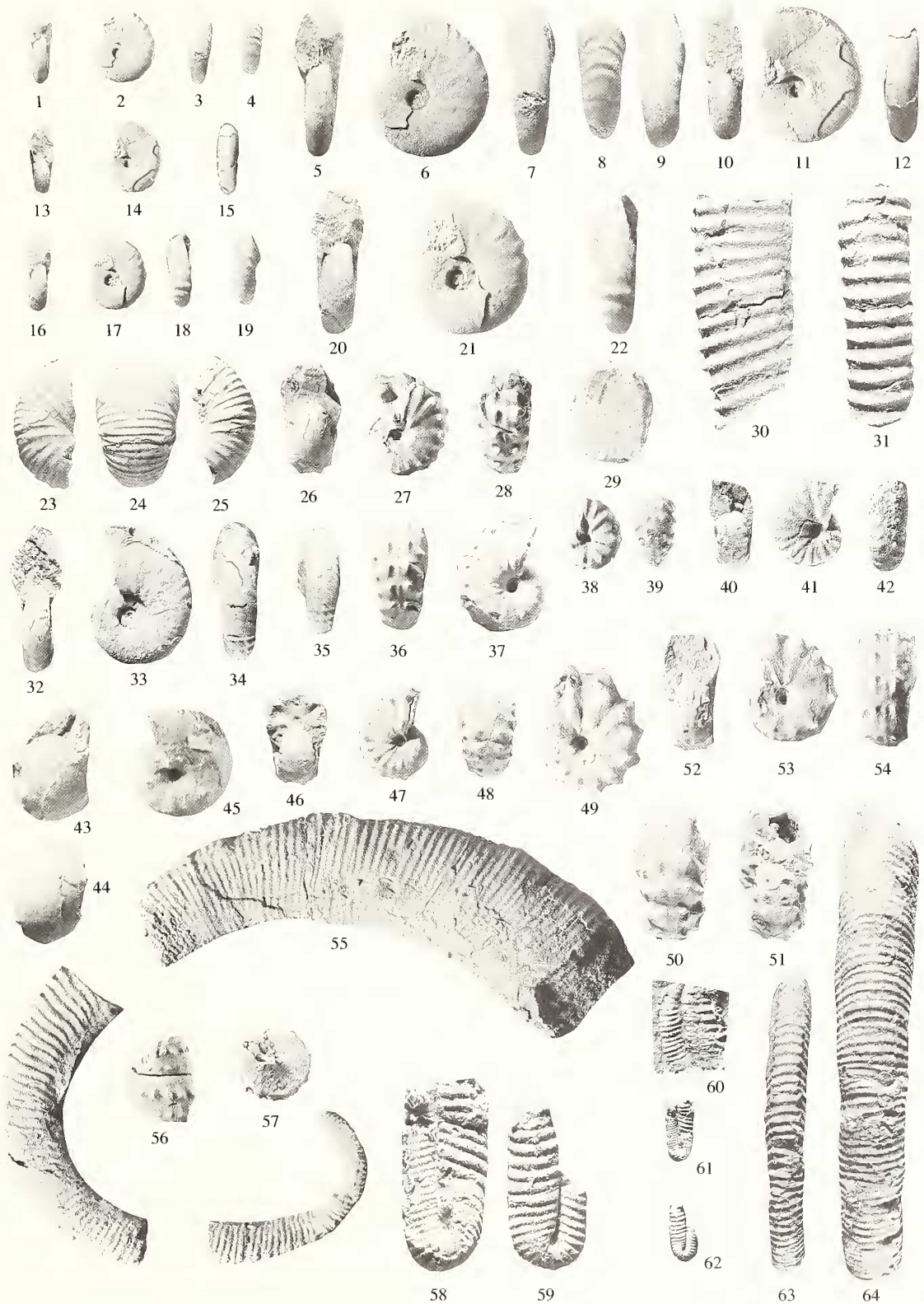
*Discussion.* These specimens closely resemble inner whorls of *Metoicoceras latoventer* Stephenson, 1953, (p. 209, pl. 53, figs. 1–9; pl. 54, figs. 9–11) from the Woodbine Formation of north Texas in their whorl inflation, ribbing style and presence of a siphonal clavus. The Wyoming specimens differ, however, in the very early loss of inner ventrolateral tubercles, which persist to the end of the adult phragmocone in the Texas material. The early loss of these tubercles is like that of the early whorls of *M. praecox* Haas, 1949, (p. 15, pls. 5–7, text-figs. 5–9). The present material probably represents an undescribed form that we are referring to as sp. A.

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EXPLANATION OF PLATE 6

- Figs. 1–22. *Alzadites incomptus* gen. et sp. nov. 1–8, paratype USNM 423726; 10–15, paratype USNM 423727; 9, 16–22, holotype USNM 423725. All specimens are from USGS Mesozoic locality D12052, *Sciponoceras gracile* zone.
- Figs. 23–25. *Scaphites* (*Scaphites*) sp. USNM 423802, from USGS Mesozoic locality 22871, *Plesiocanthoceras wyomingense* zone.
- Figs. 26–28. *Plesiocanthoceras* cf. *bellsanum* (Stephenson, 1953). USNM 423741, from USGS Mesozoic locality D5947, *Dunveganoceras pondi* zone.
- Figs. 29–31. *Hamites salebrosus* Cobban, Hook and Kennedy, 1989. USNM 423786, from USGS Mesozoic locality D8314, *Metoicoceras mosbyense* zone.
- Figs. 32–35. *Sumitomoceras* sp. USNM 423747, from USGS Mesozoic locality D12052, *S. gracile* zone.
- Figs. 36, 37, 52–54. *Plesiocanthoceras wyomingense* (Reagan, 1924). 36, 37, USNM 388161; 52–54; USNM 388159, from USGS Mesozoic locality 22871, *P. wyomingense* zone.
- Figs. 38–42. *Metoicoceras* sp. A. 38, 39, USNM 423751; 40–42, USNM 423752, from USGS Mesozoic locality D5947, *D. pondi* zone.
- Figs. 43–51. *Dunveganoceras pondi* Haas, 1949. 43–45, USNM 423744; 46–48, USNM 423745; 49–51, USNM 423746; all from USGS Mesozoic locality D4466, *D. pondi* zone.
- Figs. 55, 63, 64. *Idiohamites bispinosus* sp. nov. Paratype USNM 423793, from the Bighorn Basin of Wyoming, *D. pondi* zone.
- Figs. 56, 57. *Carthaginites aquilonius* sp. nov. Holotype USNM 423801, from USGS Mesozoic locality 12650, *M. mosbyense* zone.
- Figs. 58–62. *Metaptychoceras* spp. 58, 61, USNM 423787; 59, 62, USNM 423789, both from the Lower Turonian part of the Greenhorn Formation on the northeastern flank of the Black Hills in western South Dakota. 60, USNM 423788, from USGS Mesozoic locality D8314, *M. mosbyense* zone.
- Figs. 5–12, 20–22 are  $\times 2$ ; figs. 43–45, 58, 59 are  $\times 3$ ; the remainder are  $\times 1$ .





*Occurrence.* Known only from a single concretion at USGS Mesozoic locality D5947 in the NW $\frac{1}{4}$  sec. 14, T. 47 N., R. 65 W., Weston County, Wyoming. Upper Cenomanian zone of *Dunveganoceras pondi*.

*Metoicoceras* aff. *praecox* Haas, 1949

Plate 5, figs. 6–9; Plate 7, figs. 3–5, 14–16

Compare:

- 1949 *Metoicoceras whitei* Hyatt *praecox* Haas, p. 15, pls. 5–7; text-figs. 5–9.
- 1952 *Metoicoceras praecox* Haas; Cobban and Reeside, p. 1017.
- 1970 *Metoicoceras praecox* Haas; Ilyin, text-fig. 2E.
- 1977a *Metoicoceras* cf. *M. praecox* Haas; Cobban, p. 25, pl. 16, fig. 25; pl. 21, figs. 8 and 9.
- 1981 *Metoicoceras praecox* Haas; Kennedy, Juignet and Hancock, p. 58.

*Types.* The holotype of *M. praecox* is AMNH 26415, the original of Haas 1949, pl. 5, figs. 1, 5, 8; there are five paratypes, all from the basal part of the Cody Shale 9.7 km east and 11.2 km north of Greybull, Wyoming, in the north-central part of Township 53 N., Range 92 W.

*Material.* Four specimens, USNM 423753 to 423756, from USGS Mesozoic locality D4462, *Dunveganoceras pondi* zone.

*Description.* The earliest stages are shown by USNM 423755 and 423756, 18 and 19.5 mm in diameter respectively (Pl. 7, figs. 3–5, 14–16). Coiling is very involute, with a tiny, near-occluded umbilicus. The whorl section is depressed, polygonal in costal section. At the smallest diameter visible there are no umbilical bullae. Faint, straight prorsiradiate ribs arise low on the flank and terminate in conical inner ventrolateral tubercles; the venter is smooth. As size increases the ribs strengthen and total 13 per half whorl. They are alternately long and short, and by 16 mm diameter, weak umbilical bullae appear. The inner ventrolateral tubercles, which dominated ornament at the smallest diameter visible, decline in importance, outer ventrolateral clavi appear and strengthen, and are linked to the inner ventrolateral tubercle by a blunt rib. A low, broad swelling links the outer ventrolateral clavi and bears a weak siphonal clavus (Pl. 7, figs. 5 and 16). Larger specimens show a change to the style of ornament typical of middle growth, with bullate prorsiradiate primary ribs separated by shorter intercalatories to give an estimated 12 ribs per half whorl. The inner ventrolateral clavi are lost by a whorl height of 7 mm, although the outer ventrolateral clavi remain prominent, and the siphonal clavus is present to an estimated 25 mm diameter (Pl. 5, figs. 6–9).

*Discussion.* The earliest development of ornament of *M. praecox* has not been described, but the innermost whorls of a toptype have the same development of ornament as that of the specimens from locality D4462 except that the inner ventrolateral tubercles are lost at a smaller diameter. Ribs on the inner whorls of toptypes are also broader and more rounded than those on similar-sized specimens from locality D4462. Two of the four specimens from this locality have parts of body chambers, and it is possible that we are dealing with some diminutive species closely allied to *M. praecox*. Until more conclusive material is available, we are referring the specimens from locality D4462 to *M.* aff. *praecox*.

*Occurrence.* Known from a single limestone concretion in the Belle Fourche Shale in the NE $\frac{1}{4}$  sec. 24, T. 47 N., R. 65 W., Weston County, Wyoming. Probably low in the Upper Cenomanian zone of *Dunveganoceras pondi*.

*Metoicoceras mosbyense* Cobban, 1953

Plate 5, figs. 13–16, 23–38; Plate 7, figs. 1 and 2

- 1953 *Metoicoceras mosbyense* Cobban, p. 48, pl. 6, figs. 1–14; pl. 7, figs. 1–3.
- 1953 *Metoicoceras muelleri* Cobban, 1953, p. 49, pl. 6, figs. 15, 16; pl. 8, figs. 1–7; pl. 9.
- 1957 *Metoicoceras defordi* Young, p. 1169, pl. 149, figs. 1–8; text-fig. 1A, E, G, I.
- non 1960 *Metoicoceras muelleri* Cobban; Wiedmann, p. 720.
- non 1964 *Metoicoceras muelleri* Cobban; Wiedmann, p. 115.

- non 1967 *Metoicoceras* aff. *mosbyense* Cobban; Collignon, p. 35, pl. 19, fig. 3.  
 1970 *Metoicoceras muelleri* Cobban; Ilyin, text-fig. 2b.  
 1973 *Metoicoceras* cf. *M. defordi* Young; Cobban and Scott, p. 75.  
 1977 *Metoicoceras muelleri* Cobban; Kauffman, p. 258, pl. 21; pl. 22, figs. 17, 18.  
 non 1978 *Metoicoceras muelleri* Cobban; Wiedmann and Kauffman, pl. 6, fig. 3.  
 1979 *Metoicoceras defordi* Young; Merewether, Cobban and Cavanaugh, pl. 2, figs. 17, 20–22.  
 non 1980 *Metoicoceras muelleri* Cobban; Wiedmann, pl. 6, fig. 3.  
 1989 *Metoicoceras mosbyense* Cobban; Cobban, Hook and Kennedy, p. 43, figs. 85c–t, 86l, m.

*Type.* The holotype is USNM 108315, from the Mosby Sandstone Member of the Belle Fourche Shale of east-central Montana, *Metoicoceras mosbyense* zone.

*Material.* USNM 423757 to 423765, from USGS Mesozoic locality 8314. *M. mosbyense* zone.

*Discussion.* The present collections show the early development from 8 mm diameter onwards. At this size the coiling is very involute, with a tiny, near-occluded umbilicus (Pl. 5, figs. 13–16, 23–32; Pl. 7, figs. 1 and 2) flank ribs, no umbilical bullae and strong, conical inner ventrolateral tubercles, and weaker, clavate outer ventrolaterals. There is no trace of a siphonal row. As size increases the dominance of the inner ventrolateral tubercles declines and the outer ventrolaterals become more important, while shorter ribs with outer ventrolateral tubercles only alternate with the primaries for a short interval, although all ribs have a complete set of inner and outer ventrolateral tubercles beyond 12 mm diameter.

The largest specimens in the collection are 54 and 62 mm diameter. The former is a compressed individual that has lost its inner ventrolateral tubercles (Pl. 5, figs. 35 and 36); the latter is stouter with more robust ornament and feeble inner ventrolateral tubercles visible to 22 mm whorl height (Pl. 5, figs. 37 and 38).

The early ontogenetic stages of *M. mosbyense* are immediately separable from those of *M. latoventer* and *M. praecox*, which have siphonal tubercles. They are more like those of *M. geslinianum* (d'Orbigny, 1850), where shorter intercalated ribs without inner ventrolateral tubercles may also be present below diameters of 8 mm, and there is an earlier growth stage with prominent spinose inner ventrolateral tubercles only (Pl. 7, fig. 13).

As discussed by Cobban, Hook and Kennedy (1989), mature *M. mosbyense* are dimorphic with the type material of *mosbyense* representing the probable microconch and the type material of *M. muelleri* which is larger, more involute and weakly ornamented, as the macroconch. *M. defordi* Young, 1957 (p. 1169, pl. 149, figs. 1–8; text-fig. 1A, E, G, I) from the Upper Cenomanian of Apache County, Arizona is based on microconchs that we cannot separate from those of *M. mosbyense* and we regard it as a synonym.

*Occurrence.* *Metoicoceras mosbyense* zone of Montana and Wyoming, south to southwest New Mexico and Arizona, where it is commonly identified as *M. defordi* Young, 1957. Wiedmann (1964, 1980) records the species (as *M. muelleri*) from northern Spain, but his figured specimen belongs to some other species.

#### Genus CRYPTOMETOICOCERAS nov.

*Derivation of name.* *Kryptos* (Greek): hidden, referring to the obscure origins of the genus.

*Type species.* *Cryptometoicoceras mite* gen. et sp. nov., *Dunveganoceras pondi* zone, Wyoming.

*Diagnosis.* Very small, adult at 12 mm or less. Very involute, with tiny occluded umbilicus. Whorl section as wide as high with flattened, subparallel flanks and broadly arched venter. Phragmocone ornamented by distant, low, broad ribs that terminate at conical inner ventrolateral tubercles at the ventrolateral shoulder. Inner ventrolateral tubercles decline on adult body chamber, small rounded outer ventrolateral tubercles present on first part, thereafter disappearing. Last part of body chamber before aperture with tiny clavi on sharp ventrolateral angles linked across venter by low,



blunt, convex ribs. Suture very simple with elements only slightly incised. E is broad, E/L comparable and asymmetrically bifid, L broad and bifid, L/U<sub>2</sub> and auxiliary saddles on umbilical lobe entire.

*Discussion.* This remarkable genus is interpreted as a progenic dwarf derivative of *Metoicoceras praecox*, described above, with which it co-occurs. The earliest ornamented stages of *M. praecox* have conical inner ventrolateral tubercles only, after which outer ventrolateral and siphonal clavi appear (Pl. 7, figs. 3–5, 14–16). In *Cryptometoicoceras* all of the phragmocone corresponds to the first stage, the outer ventrolaterals are only transiently present on the first part of the adult body chamber, after which the distinctive mature ornament appears (Pl. 7, figs. 21–27). The adult *Cryptometoicoceras* is only 12 mm in diameter, the largest *M. praecox* seen are up to 138 mm in diameter.

There can be no doubt that these specimens of *Cryptometoicoceras* are adult, for they show modified body chamber ornament and the holotype has the last few sutures crowded together.

There are obvious similarities to *Nannometoicoceras* Kennedy, 1988 (p. 63, pl. 11, figs. 1–24; text-fig. 8A) with *Metoicoceras acceleratum* Hyatt, 1903 (p. 127, pl. 14, figs. 1–11) from the Upper Cenomanian *Sciponoceras gracile* zone of north-east Texas as type species, a progenic dwarf derivative of *Metoicoceras geslinianum* (d'Orbigny, 1850). Being derived by paedomorphic processes from the same genus they both have adult phragmocones with features of the nuclei of their ancestor. But whereas *Cryptometoicoceras* has only flank ribs and conical inner ventrolateral tubercles, *Nannometoicoceras* has weak to strong, flexuous primary ribs with up to three

#### EXPLANATION OF PLATE 7

- Figs. 1, 2. *Metoicoceras mosbyense* Cobban, 1953. USNM 423765, from USGS Mesozoic locality 12650, *M. mosbyense* zone.
- Figs. 3–5, 14–16. *Metoicoceras* aff. *praecox* Haas, 1949. 3–5, USNM 423755; 14–16, USNM 423756, both from USGS Mesozoic locality D4462, *Dunveganoceras pondi* zone.
- Figs. 6–9, 13. *Metoicoceras geslinianum* (d'Orbigny, 1850). 6–9, USNM 423773, from USGS Mesozoic locality 23062; 13, USNM 423722, from the Britton Formation 2.25–2.7 km (1.5–1.8 miles) southeast of Britton, Ellis County, Texas, both *Sciponoceras gracile* zone.
- Figs. 10–12. *Buccinammonites minimus* gen. et sp. nov. Holotype USNM 423770, from USGS Mesozoic locality 23062, *S. gracile* zone.
- Figs. 17–20. *Nannometoicoceras nanos* sp. nov. Holotype USNM 423768, from USGS Mesozoic locality 12740, *M. mosbyense* zone.
- Figs. 21–27. *Cryptometoicoceras mite* gen. et sp. nov. 21–24, holotype, USNM 423766; 25–27, paratype USNM 423767, both from USGS Mesozoic locality D4462, *D. pondi* zone.
- Figs. 28–31, 38–40, 48. *Nannometoicoceras?* *glabrum* sp. nov. Holotype USNM 423769, from USGS Mesozoic locality D12052, *S. gracile* zone.
- Figs. 32–37, 54, 55, 59–62. *Hamites cimarronensis* (Kauffman and Powell, 1977). 32, 33, USNM 423774; 34, USNM 423775; 35, USNM 423776; 36, 37, USNM 423777; 54, 55, USNM 423779; 59, USNM 423780; 60, USNM 423781; 61, USNM 423782; all from USGS Mesozoic locality 22871, *Plesiocanthoceras wyomingense* zone.
- Figs. 41–47, 49–53, 56–58, 65–68. *Idiohamites hispinosus* sp. nov. 41, paratype USNM 423794; 43–45, paratype USNM 423795; 46, 52, 53, paratype USNM 423796; 47, paratype USNM 423778; 49–51, paratype USNM 423797; 56, paratype USNM 423798; 57, 58, paratype USNM 423799; 65–67, holotype USNM 423792; 68, paratype USNM 423800. Figs. 41–45, 49–51 are from USGS Mesozoic locality D4466, *D. pondi* zone. Figs. 46, 52, 53, 56–58 are from USGS Mesozoic locality D5947, *D. pondi* zone. Figs. 65–67 are from USGS Mesozoic locality 22871, *P. wyomingense* zone. Fig. 68 is from USGS Mesozoic locality D4466, *D. pondi* zone.
- Figs. 63, 64, 69–71. *Idiohamites pulchellus* sp. nov. 63, 64, holotype, USNM 423790; 69–71, paratype USNM 423791, both from USGS Mesozoic locality 22871, *P. wyomingense* zone.
- Figs. 1–5, 15–16, 21–25, 38–40, 48–51, 60, 61 are  $\times 2$ ; figs. 6–13 are  $\times 3$ ; the remainder are  $\times 1$ .



intercalatories, conical inner *and* outer ventrolateral tubercles, the latter projected adaperturally of the former, or tubercles only. Body chambers of *Nannometoicoceras* have primary ribs that are bullate or not with 2–3 intercalatories between, and conical to clavate inner and clavate outer ventrolateral tubercles that persist to the end of the body chamber.

*Occurrence.* *Dunveganoceras pondi* zone, Wyoming.

*Cryptometoicoceras mite* gen. et sp. nov.

Plate 7, figs. 21–27

*Types.* Holotype is USNM 423766; paratype USNM 423767, from USGS Mesozoic locality D4462, *D. pondi* zone.

*Derivation of name.* *Mite*, small.

*Diagnosis.* With the characters of the genus.

*Description.* The holotype is an incomplete adult lacking the adapical part of the body chamber. Its essential characteristics are incorporated in the generic diagnosis. Paratype USNM 423767 is a body chamber fragment of comparable size to the holotype. It has ribs at the adapical end with both inner and outer ventrolateral tubercles, those at the adapical end have lost the outer ventrolateral tubercles and are markedly strengthened, suggesting that this specimen too is an adult.

*Occurrence.* As for types.

Genus NANNOMETOICOCERAS Kennedy, 1988

*Type species.* *Metoicoceras acceleratum* Hyatt, 1903, p. 127, pl. 14, figs. 1–11. Upper Cenomanian *Sciponoceras gracile* zone of north-east Texas.

*Nannometoicoceras nanos* sp. nov.

Plate 7, figs. 17–20

*Derivation of name.* *Nanos* (Greek): a dwarf.

*Types.* Holotype is USNM 423768, from USGS Mesozoic locality 12740, *Metoicoceras mosbyense* zone.

*Diagnosis.* Adult at 12–13 mm diameter. Late phragmocone and early body chamber with conical inner and outer ventrolateral tubercles. Late body chamber with smooth flanks and strong, nontuberculate ventral ribs.

*Description.* Holotype is a complete adult no more than 13 mm diameter. Coiling very involute with minute, near-occluded umbilicus. Whorl section compressed (whorl breadth to height ratio 0.6 approximately), with flattened, subparallel flanks, narrowly rounded ventrolateral shoulders and a flattened venter. No umbilical bullae on phragmocone or body chamber. Weak, distant, long and short ribs alternate more-or-less regularly. All terminate in a conical inner ventrolateral tubercle, of which there are five or six on the first half of the outer whorl. Corresponding to these are minute, feebly clavate, outer ventrolateral tubercles. Tubercles disappear on last section of body chamber, where there are five broad, blunt ventral ribs preserved just before the adult aperture. Last few sutures are crowded, indicating maturity, and are very simple, with narrow E/L and broad, bifid L.

*Discussion.* Small size, absence of umbilical bullae and of strong flank and ventral ribs on the greater part of the body chamber immediately distinguish *N. nanos* sp. nov., from the type species *N.*



*acceleratum* (Kennedy, 1988, p. 67, pl. 11, figs. 1–24; text-fig. 8A). There are obvious similarities to *Cryptometoiceras mite* gen. et sp. nov. (p. 411, Pl. 7, figs. 21–27) which has the same terminal body chamber ornament, but *N. nanos* sp. nov. has inner and outer ventrolateral tubercles on the phragmocone whereas *C. mite* lacks the outer ventrolateral. The adult phragmocone of *N. nanos* sp. nov., closely resembles that of juvenile *Metoiceras mosbyense* (Pl. 7, figs. 1 and 2) of which it is presumed to be a progenic dwarf derivative.

*Occurrence.* As for type.

*Nannometoiceras? glabrum* sp. nov.

Plate 7, figs. 28–31, 38–40, 48

*Derivation of name.* *Glaber* (Latin): smooth.

*Type.* Holotype is USNM 423769 from USGS Mesozoic locality D12052, *Sciponoceras gracile* zone.

*Diagnosis.* Small, adult at 11 mm diameter. Phragmocone and early body chamber with distant, conical, outer ventrolateral tubercles followed by a shallow ventral constriction, four on the first half of the outer whorl. Middle section of body chamber with low folds and constrictions, final part with four coarse ventrolateral and ventral ribs, the venter markedly flattened before the adult aperture.

*Description.* Holotype is adult at 11 mm diameter. Coiling is very involute with a tiny umbilicus. Whorl section compressed with a broadly rounded venter on the phragmocone. Phragmocone and early body chamber smooth except for distant, conical, outer ventrolateral tubercles, four on the first half of the outer whorl. Venter of middle part of body chamber with low folds. Last part of body chamber has flattened venter in costal section, with four coarse, ventral and ventrolateral ribs separated by deep, wide interspaces. Ribs are transverse on the venter, concave on the ventrolateral shoulder, and connected to the umbilicus by a delicate lira.

Sutures not seen.

*Discussion.* Absence of inner ventrolateral tubercles distinguish this species from all other *Nannometoiceras* and from *Cryptometoiceras mite* gen. et sp. nov. The absence of inner ventrolaterals suggests that, given additional material it might merit subgeneric status within *Nannometoiceras*. There is no clear indication of its evolutionary origins.

*Occurrence.* As for type.

Genus BUCCINAMMONITES nov.

*Derivation of name.* *Buccina* (Latin): trumpet, in reference to the trumpet-like flared aperture.

*Type species.* *Buccinammonites minimus* gen. et sp. nov., *Sciponoceras gracile* zone, southeastern Montana.

*Diagnosis.* Minute, adult at 4.5 mm diameter. Very involute with tiny umbilicus. Whorl section depressed with flattened subparallel flanks, venter broadly rounded. Five ribs per half whorl on the phragmocone are broad and coarse and terminate in strong conical inner ventrolateral tubercles. This style of ornament persists onto the first part of the adult body chamber. Aperture preceded by narrow crowded ribs with minute ventrolateral tubercles. Mouth border with flare that extends out for 30 % of the whorl height in a trumpet-like aperture. Suture with very simple, little-incised bifid elements.

*Discussion.* Minute size, simple ornament and the extraordinary flared aperture distinguish *Buccinammonites* gen. nov., from all other described taxa. The coiling and proportions of the

phragmocone whorls recall those of *Cryptometoicoceras* gen. nov., but the body chamber ornament is utterly distinctive. Like *Nannometoicoceras* and *Cryptometoicoceras*, the phragmocone ornament of *Buccinammonites* indicates that it is a progenic dwarf derivative of some other metoicoceratine, but whether this was *Metoicoceras* (Pl. 7, figs. 1–9, 14–16) where the earliest ornamented stage has only flank ribs and inner ventrolateral tubercles or the already dwarf *Nannometoicoceras* or *Cryptometoicoceras*, we cannot say.

*Occurrence.* As for genus.

*Buccinammonites minimus* gen. et sp. nov.

Plate 7, figs. 10–12

*Derivation of name.* *Minimus* (Latin): least.

*Types.* Holotype USNM 423770, paratype USNM 423771, from USGS Mesozoic locality 23062, *Sciponoceras gracile* zone.

*Diagnosis.* With the characters of the genus.

*Discussion.* The holotype is a complete adult showing all the diagnostic features of the species. Paratype USNM 423771 is incomplete at 4.8 mm diameter and has shallow constrictions.

*Occurrence.* As for types.

Suborder ANCYLOCERATINA Wiedmann, 1966, p. 54

Superfamily TURRILITACEAE Gill, 1871, p. 3

Family HAMITIDAE Gill, 1871, p. 3

Genus HAMITES Parkinson, 1811, p. 145

(= *Torneutoceras* Hyatt, 1900, p. 586 (objective synonym); *Stomohamites* Breistroffer, 1940, p. 85; *Hamitella* Breistroffer, 1947, p. 100 (84) *nom. nov. pro. Helicoceras* d'Orbigny, 1842, p. 611, *non* Koenig, 1825, pl. 19).

*Type species.* *Hamites attenuatus* J. Sowerby, 1814, p. 137, pl. 61, figs. 4 and 5, by the subsequent designation of Diener 1925, p. 65.

*Hamites cimarronensis* (Kauffman and Powell, 1977)

Plate 7, figs. 32–37, 54, 55, 59–62

1953 *Hamites?* sp. Stephenson, p. 197.

1977 *Stomohamites simplex cimarronensis* Kauffman and Powell, p. 97, pl. 9, figs. 1, 3, 4; text-figs. 5 and 6.

1990 *Hamites cimarronensis* (Kauffman and Powell, 1977); Kennedy and Cobban, p. 140, pl. 15, figs. 11, 13, 15, 17, 19–21.

*Type.* Holotype is USNM 167160, the original of Kauffman and Powell 1977, pl. 9, fig. 1, from USGS Mesozoic locality 30235 in Cimarron County, Oklahoma, and from the Hartland Member of the Greenhorn Limestone, late Cenomanian.

*Material.* More than 100 fragments from USGS Mesozoic localities D5947, D4462, D4466 and D22871, *Plesiacanthoceras wyomingense* to *Dunveganoceras pondi* zones.

*Discussion.* Fragments of this species are very common in the present collections. The very earliest developmental stages generally lack the protoconch and consist of a straight, smooth, slowly expanding shaft up to 12 mm long (Pl. 7, figs. 59–61). This shaft is terminated by a curved section,

at which point ribbing develops. The largest fragment seen has a whorl height of 10 mm, and is part of a curved portion (Pl. 7, fig. 62). It and fragments of intermediate size suggest an elliptical coiling with at least three shafts. Ornament consists of fine, dense, prorsiradiate ribs that are weakest on the dorsum and strongest over the venter, straight to feebly convex, with a rib index of 6–8. Most of the material is much smaller than that of the European *H. simplex* d'Orbigny, 1842 (p. 550, pl. 134, figs. 12–14) making comparison difficult, but large fragments are always much more densely ribbed than the comparable stage of *H. simplex*.

Occurrence. Widespread in the US Western Interior from Montana and Wyoming south to New Mexico and northeast Texas, ranging from *Confinoceras tarrantense* to *Dunveganoceras pondi* zones.

*Hamites salebrosus* Cobban, Hook and Kennedy, 1989

Plate 6, figs. 29–31

1989 *Hamites salebrosus* Cobban, Hook and Kennedy, p. 57, fig. 95bb, cc, ii.

*Type*. Holotype is USNM 423786 from USGS Mesozoic locality D12069 in Apache County, New Mexico, Twowells Sandstone Tongue of Dakota Sandstone, *Metoicoceras mosbyense* zone.

*Material*. USNM 423786 from USGS Mesozoic locality D8314. *M. mosbyense* zone.

*Description and Discussion*. Specimen is a body chamber fragment 46 mm long with a maximum preserved whorl height of 17.5 mm. The whorl section is a compressed oval with a whorl breadth to height ratio of 0.7. The rib index is 5, the ribs weakened somewhat on the dorsum but strengthening across the flanks, where they are straight and prorsiradiate, and passing straight across the venter. Large size, coarse ribbing, compression and low rib density distinguish *H. salebrosus* from all other described species.

*Occurrence*. *Calycoceras canitaurinum* and *M. mosbyense* zones, New Mexico, Arizona and Wyoming.

Genus METAPTYPCHOCERAS Spath, 1926, p. 80

*Type species*. *Ptychoceras smithi* Woods, 1896, p. 74, pl. 2, figs. 1 and 2, by original designation.

*Metaptychoceras* spp.

Plate 6, figs. 58–62

Compare:

1977 *Hemiptychoceras* sp. Kauffman and Powell, p. 99, pl. 9, fig. 5; text-fig. 7.

*Material*. USNM 423788, from USGS Mesozoic locality D8314, *M. mosbyense* zone; USNM 423787 and 423789 from the Greenhorn Formation of western South Dakota.

*Discussion*. USNM 423788 is an external mould of two shafts, with a maximum preserved length of 7.5 mm. The smaller shaft is curved and ornamented by strong, straight, weakly prorsiradiate ribs; the rib index is 4–5. The larger shaft has coarser ribs; the rib index is 5. *Metaptychoceras* is generally uncommon in the US Western Interior. It occurs in the middle Cenomanian of Oklahoma (Kauffman and Powell 1977) and Wyoming (the present record), *C. canitaurinum* zone of New Mexico, *S. gracile* zone of Colorado and northeast Texas, lower Turonian of the Dallas area in Texas and the northeast flank of the Black Hills in western South Dakota (Pl. 6, figs. 58, 59, 61, 62) and is locally frequent in the upper Turonian in the Waco area in central Texas and Chispa Summit in Trans-Pecos Texas.



Family ANISOCERATIDAE Hyatt, 1900, p. 587  
 (= Algeritidae Spath, 1925, p. 190)  
 Genus IDIOHAMITES Spath, 1925

*Type species.* *Hamites tuberculatus* J. Sowerby, 1818, p. 30, pl. 216, figs 4 and 5, by original designation.

*Idiohamites pulchellus* sp. nov.

Plate 7, figs. 63, 64, 69–71

1973 *Idiohamites* sp. Cobban and Scott, p. 50, pl. 13, figs. 1–4.

*Derivation of name.* Diminutive of *pulcher* (Latin): beautiful.

*Types.* Holotype is USNM 423790, paratype is USNM 423791, from USGS Mesozoic locality 22871, *Plesiacanthoceras wyomingense* zone.

*Diagnosis.* Compressed *Idiohamites* with narrow prorsiradiate ribs, rib index 9. Periodically strengthened ribs have sharp lower lateral and ventrolateral tubercles, typically with 3–4 non-tuberculate ribs between.

*Discussion.* The holotype is a slightly curved fragment 25 mm long and shows a transition from an initially bituberculate section. Paratype USNM 423971 is much larger, with a whorl height of 11.5 mm and a rib index of 9, showing the same differentiation into stronger tuberculate ribs separated by up to five non-tuberculate ones. *I. pulchellus* sp. nov., is easily distinguished from *I. bispinosus* sp. nov., to be described below, which is the only other species known from the Western Interior, and which lacks lateral tubercles.

*Occurrence.* *Conlinoceras tarrantense* and *Acanthoceras muldoonense* zones of southeastern Colorado, *Plesiacanthoceras wyomingense* zone of Montana.

*Idiohamites bispinosus* sp. nov.

Plate 6, figs. 55, 63, 64; Plate 7, figs. 41–47, 49–53, 56–58, 65–68

*Types.* Holotype is USNM 423792, from USGS Mesozoic locality 22871, *P. wyomingense* zone. Paratypes USNM 423796, 423798 and 423799 are from USGS Mesozoic locality 5947; paratype USNM 423800 is from USGS Mesozoic locality D4466; paratypes USNM 423794, 423795 and 423797 are from USGS Mesozoic locality D4462; paratype USNM 423793 is from the Bighorn Basin of Wyoming; all from the *Dunveganoceras pondi* zone.

*Diagnosis.* Planispirally coiled in an open ellipse. Whorl section compressed oval with crowded, prorsiradiate, feebly convex ribs. One, sometimes two, linked ribs bear sharp ventrolateral tubercles on moulds that are the bases of septate spines linked across the venter by a pair of looped ribs. There are 1–3 non-tuberculate ribs between the tuberculate ones.

*Discussion.* Specimens range from 2 to 10 mm whorl height. At the smallest sizes there may be some irregularities in ribbing with up to five non-tuberculate ribs between tuberculate ones, and the very earliest stages may lack tubercles. The septate spines are perfectly preserved in USNM 423798 (Pl. 7, fig 56).

What may be an adult of the species is represented by USNM 423793, from the Upper Cenomanian *Dunveganoceras pondi* zone near Greybull, Wyoming (Pl. 6, figs. 55, 63, 64). The three fragments illustrated were originally part of a single specimen. The smallest piece closely resembles the type series. The middle piece, from a whorl height of 8.5 to 13 mm has a rib index of 8, the ribs

flexuous and prorsiradiate, and nearly all with a ventral tubercle. The largest fragment, preserved to a whorl height of 22 mm has a rib index of 16, with tuberculate ribs separated by up to three non-tuberculate ones on the first part, after which the ribs are all non-tuberculate for the final 65 mm.

Absence of lateral tubercles easily distinguishes *I. bispinosus* sp. nov., from *I. pulchellus* sp. nov., the only other species known from the Western Interior.

*Occurrence.* *Plesiacanthoceras wyomingense* and *Dunveganoceras pondi* zones of Wyoming and Montana.

Family TURRILITIDAE Gill, 1871, p. 3  
(= Pseudhelicoceratinae Breistroffer, 1953, p. 1350)  
Genus CARTHAGINITES Pervinquier, 1907, p. 96

*Type species.* *Turrilites* (*Carthaginites*) *kerimensis* Pervinquier, 1907, p. 101, pl. 4, fig. 18.

*Carthaginites aquilonius* sp. nov.

Plate 6, figs. 56 and 57

*Derivation of name.* *Aquilonius* (Latin): northerly.

*Type.* Holotype is USNM 423801 from USGS Mesozoic locality 12650, *Metoicoceras mosbyense* zone.

*Description.* Specimen consists of one and a quarter whorls, with a maximum preserved whorl height of 6.9 mm. Apical angle low, with seam between successive whorls only slightly indented. 17–18 low, broad, prorsiradiate ribs arise at the upper edge of the outer whorl face and strengthen into small, sharp tubercles a little above the middle of the outer whorl face. A broad, smooth, depressed zone separates these from a row of small, blunt, aperturally displaced tubercles low on the outer whorl face. These show feeble spiral elongation and lie at a sharp angulation in the whorl profile and pronounced facet that extends to the lower edge of the outer whorl. The sharp edge between outer and lower whorl faces is feebly crenulate, the crenulations corresponding in position and number to the lowest row of tubercles.

*Discussion.* The imperfectly exposed suture shows E/L occupying the upper outer and part of the upper whorl face, confirming this as a *Carthaginites* rather than *Neostlingoceras*. The presence of strong tubercles immediately distinguishes it from *C. krorzaensis* Dubourdieu, 1953 (p. 66, pl. 49, figs. 49–52; text-fig. 20). *C. kerimensis* Pervinquier, 1907, (p. 101, pl. 4, fig. 18) is based upon a minute specimen with only 6–7 mid-flank tubercles per whorl, and no lower row. *Carthaginites virdense* Cobban, Hook and Kennedy (1989) has 12–13 tuberculate ribs in the upper row, and those in the lower row twice as numerous.

Superficially similar is *Neostlingoceras kottlowski* Cobban and Hook, 1981 (p. 26, pl. 4, figs. 1–28), which has a third row of tubercles on the underside of the whorl.

*Occurrence.* As for type.

Superfamily SCAPHITACEAE Gill, 1871, p. 3  
(*nom. transl.* Wright and Wright, 1951, p. 13, *ex* Scaphitidae Gill, 1871, p. 3)  
Family SCAPHITIDAE Gill, 1871, p. 3  
Subfamily SCAPHITINAE Gill, 1871, p. 3  
(*nom. transl.* Wright, 1953, p. 473, *ex* Scaphitidae Gill, 1871, p. 3)  
Genus and subgenus SCAPHITES Parkinson, 1811, p. 3.

*Type species.* *Scaphites equalis* J. Sowerby, 1813, p. 53, pl. 18, figs. 1–3.

*Scaphites (Scaphites) sp.*

Plate 6, figs. 23–25

*Material.* USNM 423802, from USGS Mesozoic locality 22871, *Plesiacanthoceras wyomingense* zone.

*Description.* Specimen is a wholly septate fragment of less than half a whorl with a maximum preserved whorl height of 9 mm. Coiling very involute, with a depressed, reniform whorl section. Narrow primary ribs arise at the umbilical seam and secondary ribs are inserted between them, both high and low on the flank. Ribs are narrow, straight and prorsiradiate, and cross the venter nearly straight. The last half of the fragment bears small, conical, ventrolateral tubercles on four out of nine primary ribs. Each tubercle gives rise to a pair of ribs that loop across the venter to the tubercle on the other flank.

*Discussion.* This is the only *Scaphites (Scaphites)* known from the Western Interior below the zone of *Sciponoceras gracile* (see Cobban, 1952 for details).

*Occurrence.* As for material.

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